CARNEGIE INSTITUTION

OF

WASHINGTON

YEAR BOOK No. 15

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OFFICERS FOR THE YEAR 1917.

LIST OF PRESENT AND FORMER TRUSTEES.

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ORGANIZATION, PLAN AND SCOPE.

The Carnegie Institution of Washington was founded by Mr. Andrew Carnegie, January 28, 1902, when he gave to a board of trustees an endowment of registered bonds of the par value of ten million dollars. To this fund an addition of two million dollars was made by Mr. Carnegie on December 10, 1907, and a further addition of ten million dollars was made by him January 19, 1911; so that the present endowment of the Institution has a par value of twenty-two million dollars. The Institution was originally organized under the laws of the District of Columbia and incorporated as the *Carnegie Institution*, articles of incorporation having been executed on January 4, 1902. The Institution was reincorporated, however, by an act of the Congress of the United States, approved April 28, 1904, under the title of *The Carnegie Institution of Washington*. (See existing Articles of Incorporation on the following pages.)

Organization under the new Articles of Incorporation was effected May 18, 1904, and the Institution was placed under the control of a board of twenty-four trustees, all of whom had been members of the original corporation. The trustees meet annually in December to consider the affairs of the Institution in general, the progress of work already undertaken, the initiation of new projects, and to make the necessary appropriations for the ensuing year. During the intervals between the meetings of the Trustees the affairs of the Institution are conducted by an Executive Committee chosen by and from the Board of Trustees and acting through the President of the Institution as chief executive officer.

The Articles of Incorporation of the Institution declare in general "that the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind." Three principal agencies to forward these objects have been developed. The first of these involves the establishment of departments of research within the Institution itself, to attack larger problems requiring the collaboration of several investigators, special equipment, and continuous effort. The second provides means whereby individuals may undertake and carry to completion investigations not less important but requiring less collaboration and less special equipment. The third agency, namely, a division devoted to editing and to printing books, aims to provide adequate publication of the results of research coming from the first two agencies and to a limited extent also for worthy works not likely to be published under other auspices.

ARTICLES OF INCORPORATION.

Public No. 260.—An Act To incorporate the Carnegie Institution of Washington.

Be in enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the persons following, being persons who are now trustees of the Carnegie Institution, namely, Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, their associates and successors, duly chosen, are hereby incorporated and declared to be a body corporate by the name of the Carnegie Institution of Washington and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions herein contained.

Sec. 2. That the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind; and in particular—

(a) To conduct, endow, and assist investigation in any department of science, literature, or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies, and individuals.

(b) To appoint committees of experts to direct special lines of research.

(c) To publish and distribute documents.

(d) To conduct lectures, hold meetings and acquire and maintain a library.

(e) To purchase such property, real or personal, and construct such building or buildings as may be necessary to carry on the work of the corporation.

(f) In general, to do and perform all things necessary to promote the objects of the institution, with full power, however, to the trustees hereinafter appointed and their successors from time to time to modify the conditions and regulations under which the work shall be carried on, so as to secure the application of the funds in the manner best adapted to the conditions of the time, provided that the objects of the corporation shall at all times be among the foregoing or kindred thereto.

Sec. 3. That the direction and management of the affairs of the corporation and the control and disposal of its property and funds shall be vested in a board of trustees, twenty-two in number, to be composed of the following individuals: Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D.

Wright, who shall constitute the first board of trustees. The board of trustees shall have power from time to time to increase its membership to not more than twenty-seven members. Vacancies occasioned by death, resignation, or otherwise shall be filled by the remaining trustees in such manner as the by-laws shall prescribe; and the persons so elected shall thereupon become trustees and also members of the said corporation. The principal place of business of the said corporation shall be the city of Washington, in the District of Columbia.

SEC. 4. That such board of trustees shall be entitled to take, hold and administer the securities, funds, and property so transferred by said Andrew Carnegie to the trustees of the Carnegie Institution and such other funds or property as may at any time be given, devised, or bequeathed to them, or to such corporation, for the purposes of the trust; and with full power from time to time to adopt a common seal, to appoint such officers, members of the board of trustees or otherwise, and such employees as may be deemed necessary in carrying on the business of the corporation, at such salaries or with such remuneration as they may deem proper; and with full power to adopt by-laws from time to time and such rules or regulations as may be necessary to secure the safe and convenient transaction of the business of the corporation; and with full power and discretion to deal with and expend the income of the corporation in such manner as in their judgment will best promote the objects herein set forth and in general to have and use all powers and authority necessary to promote such objects and carry out the purposes of the donor. The said trustees shall have further power from time to time to hold as investments the securities hereinabove referred to so transferred by Andrew Carnegie, and any property which has been or may be transferred to them or such corporation by Andrew Carnegie or by any other person, persons, or corporation, and to invest any sums or amounts from time to time in such securities and in such form and manner as are permitted to trustees or to charitable or literary corporations for investment, according to the laws of the States of New York, Pennsylvania, or Massachusetts, or in such securities as are authorized for investment by the said deed of trust so executed by Andrew Carnegie, or by any deed of gift or last will and testament to be hereafter made or executed.

SEC. 5. That the said corporation may take and hold any additional donations, grants, devises, or bequests which may be made in further support of the purposes of the said corporation, and may include in the expenses thereof the personal expenses which the trustees may incur in attending meetings or otherwise in carrying out the business of the trust, but the services of the trustees as such shall be gratuitous.

SEC. 6. That as soon as may be possible after the passage of this Act a meeting of the trustees hereinbefore named shall be called by Daniel C. Gilman, John S. Billings, Charles D. Walcott, S. Weir Mitchell, John Hay, Elihu Root, and Carroll D. Wright, or any four of them, at the city of Washington, in the District of Columbia, by notice served in person or by mail addressed to each trustee at his place of residence; and the said trustees, or a majority thereof, being assembled, shall organize and proceed to adopt by-laws, to elect officers and appoint committees, and generally to organize the said corporation; and said trustees herein named, on behalf of the corpora-

tion hereby incorporated, shall thereupon receive, take over, and enter into possession, custody, and management of all property, real or personal, of the corporation heretofore known as the Carnegie Institution, incorporated, as hereinbefore set forth under "An Act to establish a Code of Law for the District of Columbia, January fourth, nineteen hundred and two," and to all its rights, contracts, claims, and property of any kind or nature; and the several officers of such corporation, or any other person having charge of any of the securities, funds, real or personal, books or property thereof, shall, on demand, deliver the same to the said trustees appointed by this Act or to the persons appointed by them to receive the same; and the trustees of the existing corporation and the trustees herein named shall and may take such other steps as shall be necessary to carry out the purposes of this Act.

SEC. 7. That the rights of the creditors of the said existing corporation known as the Carnegie Institution shall not in any manner be impaired by the passage of this Act, or the transfer of the property hereinbefore mentioned, nor shall any liability or obligation for the payment of any sums due or to become due, or any claim or demand, in any manner or for any cause existing against the said existing corporation, be released or impaired; but such corporation hereby incorporated is declared to succeed to the obligations and liabilities and to be held liable to pay and discharge all of the debts, liabilities, and contracts of the said corporation so existing to the same effect as if such new corporation had itself incurred the obligation or liability to pay such debt or damages, and no such action or proceeding before any court or tribunal shall be deemed to have abated or been discontinued by reason of the passage of this Act.

SEC. 8. That Congress may from time to time alter, repeal, or modify this Act of incorporation, but no contract or individual right made or acquired shall thereby be divested or impaired.

SEC. 9. That this Act shall take effect immediately.

Approved, April 28, 1904.

BY-LAWS OF THE INSTITUTION.

Adopted December 13, 1904. Amended December 13, 1910, and **December 13, 1912.**

Article I.

THE TRUSTEES.

1. The Board of Trustees shall consist of twenty-four members, with power to increase its membership to not more than twenty-seven members The Trustees shall hold office continuously and not for a stated term.

2. In case any Trustee shall fail to attend three successive annual meetings of the Board he shall thereupon cease to be a Trustee.

3. No Trustee shall receive any compensation for his services as such.

4. All vacancies in the Board of Trustees shall be filled by the Trustees by ballot. Sixty days prior to an annual or a special meeting of the Board, the President shall notify the Trustees by mail of the vacancies to be filled and each Trustee may submit nominations for such vacancies. A list of the persons so nominated, with the names of the proposers, shall be mailed to the Trustees thirty days before the meeting, and no other nominations shall be received at the meeting except with the unanimous consent of the Trustees present. Vacancies shall be filled from the persons thus nominated, but no person shall be declared elected unless he receives the votes of two-thirds of the Trustees present.

Article II.

MEETINGS.

1. The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the first Friday following the second Thursday of December in each year.

2. Special meetings of the Board may be called by the Executive Committee by notice served personally upon, or mailed to the usual address of, each Trustee twenty days prior to the meeting.

3. Special meetings shall, moreover, be called in the same manner by the Chairman upon the written request of seven members of the Board.

Article III.

OFFICERS OF THE BOARD.

1. The officers of the Board shall be a Chairman of the Board, a Vice-Chairman, and a Secretary, who shall be elected by the Trustees, from the members of the Board, by ballot to serve for a term of three years. All vacancies shall be filled by the Board for the unexpired term; provided, however, that the Executive Committee shall have power to fill a vacancy in the office of Secretary to serve until the next meeting of the Board of Trustees.

2. The Chairman shall preside at all meetings and shall have the usual powers of a presiding officer.

3. The Vice-Chairman, in the absence or disability of the Chairman, shall perform his duties.

4. The Secretary shall issue notices of meetings of the Board, record its transactions, and conduct that part of the correspondence relating to the Board and to his duties. He shall execute all deeds, contracts or other instruments on behalf of the corporation, when duly authorized.

Article IV.

EXECUTIVE ADMINISTRATION.

The President.

1. There shall be a President who shall be elected by ballot by, and hold office during the pleasure of, the Board, who shall be the chief executive officer of the Institution. The President, subject to the control of the Board and the Executive Committee, shall have general charge of all matters of administration and supervision of all arrangements for research and other work undertaken by the Institution or with its funds. He shall devote his entire time to the affairs of the Institution. He shall prepare and submit to the Board of Trustees and to the Executive Committee plans and suggestions for the work of the Institution, shall conduct its general correspondence and the correspondence with applicants for grants and with the special advisers of the Committee, and shall present his recommendations in each case to the Executive Committee for decision. All proposals and requests for grants shall be referred to the President for consideration and report. He shall have power to remove and appoint subordinate employees and shall be *ex officio* a member of the Executive Committee.

2. He shall be the legal custodian of the seal and of all property of the Institution whose custody is not otherwise provided for. He shall affix the seal of the corporation whenever authorized to do so by the Board of Trustees or by the Executive Committee or by the Finance Committee. He shall be responsible for the expenditure and disbursement of all funds of the Institution in accordance with the directions of the Board and of the Executive Committee, and shall keep accurate accounts of all receipts and disbursements. He shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board.

3. He shall attend all meetings of the Board of Trustees.

Article V.

COMMITTEES.

1. There shall be the following standing Committees, viz., an Executive Committee, a Finance Committee, and an Auditing Committee.

2. The Executive Committee shall consist of the Chairman and Secretary of the Board of Trustees and the President of the Institution *ex officio* and, in addition, five trustees to be elected by the Board by ballot for a term of three years, who shall be eligible for re-election. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term: Provided, however, that of the Executive Committee first elected after the adoption of these by-laws two shall serve for one year, two shall serve for two years, and one shall serve for three years; and such Committee shall determine their respective terms by lot.

3. The Executive Committee shall, when the Board is not in session and has not given specific directions, have general control of the administration of the affairs of the corporation and general supervision of all arrangements for administration, research, and other matters undertaken or promoted by the Institution; shall appoint advisory committees for specific duties; shall determine all payments and salaries; and keep a written record of all transactions and expenditures and submit the same to the Board of Trustees at each meeting, and it shall also submit to the Board of Trustees a printed or typewritten report of each of its meetings, and at the annual meeting shall submit to the Board a report for publication.

4. The Executive Committee shall have general charge and control of all appropriations made by the Board.

5. The Finance Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

6. The Finance Committee shall have custody of the securities of the corporation and general charge of its investments and invested funds, and shall care for and dispose of the same subject to the directions of the Board of Trustees. It shall consider and recommend to the Board from time to time such measures as in its opinion will promote the financial interests of the Institution, and shall make a report at each meeting of the Board.

7. The Auditing Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

8. The Auditing Committee shall, before each annual meeting of the Board of Trustees, examine the accounts of business transacted under the Finance Committee and the Executive Committee. They may avail themselves at will of the services and examination of the Auditor appointed by the Board of Trustees. They shall report to the Board upon the collection of moneys to which the Institution is entitled, upon the investment and reinvestment of principal, upon the conformity of expenditures to appropriations, and upon the system of bookkeeping, the sufficiency of the accounts, and the safety and economy of the business methods and safeguards employed.

9. All vacancies occurring in the Executive Committee and the Finance Committee shall be filled by the Trustees at the next regular meeting. In case of vacancy in the Finance Committee or the Auditing Committee, upon request of the remaining members of such committee, the Executive Committee may fill such vacancy by appointment until the next meeting of the Board of Trustees.

10. The terms of all officers and of all members of committees shall continue until their successors are elected or appointed.

Article VI.

FINANCIAL ADMINISTRATION.

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Board of Trustees.

2. The fiscal year of the Institution shall commence on the first day of November in each year.

3. The Executive Committee, at least one month prior to the annual meeting in each year, shall cause the accounts of the Institution to be audited by a skilled accountant, to be appointed by the Board of Trustees, and shall submit to the annual meeting of the Board a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year.

4. The Board of Trustees, at the annual meeting in each year, shall make general appropriations for the ensuing fiscal year; but nothing contained herein shall prevent the Board of Trustees from making special appropriations at any meeting.

5. The securities of the Institution and evidences of property, and funds invested and to be invested, shall be deposited in such safe depository or in the custody of such trust company and under such safeguards as the Trustees and Finance Committee shall designate; and the income available for expenditure of the Institution shall be deposited in such banks or depositories as may from time to time be designated by the Executive Committee.

6. Any trust company entrusted with the custody of securities by the Finance Committee may, by resolution of the Board of Trustees, be made Fiscal Agent of the Institution, upon an agreed compensation, for the transaction of the business coming within the authority of the Finance Committee.

Article VII.

AMENDMENT OF BY-LAWS.

1. These by-laws may be amended at any annual or special meeting of the Board of Trustees by a two-thirds vote of the members present, provided written notice of the proposed amendment shall have been served personally upon, or mailed to the usual address of, each member of the Board twenty days prior to the meeting.

MINUTES

OF THE

FIFTEENTH MEETING OF THE BOARD OF TRUSTEES

to fill the first-named vacancy resulted in the election of Mr. John J. Carty, of New York, to membership in the Board.

Mr. Welch submitted his resignation as a member of the Executive Committee, which, upon motion, was accepted with regret.

Mr. Stewart Paton was elected to fill the vacancy caused by the resignation of Mr. Welch.

The following resolutions were passed:

Resolved, That inasmuch as the work of publication of the Classics of International Law lies more properly within the domain of the Carnegie Endowment for International Peace, the action of the Executive Committee in authorizing the transfer of this project to said Endowment in accordance with preliminary plans outlined by the President, and subject to the approval of the Board of Trustees, be and hereby is approved.

Resolved, That the Department of Economics and Sociology, as now constituted, be and hereby is discontinued.

Resolved, That, subject to approval by the Executive Committee of specific allotments, the balance of appropriations, namely, $16,829.84, remaining to the credit of the Department of Economics and Sociology, be and hereby is made available for use by the group of collaborators who were formerly members of this department.

The Board adjourned at $12^h\ 40^m$ a. m.

REPORT OF THE PRESIDENT

OF THE

CARNEGIE INSTITUTION OF WASHINGTON

FOR THE YEAR ENDING OCTOBER 31, 1916.

REPORT OF THE PRESIDENT
OF THE
CARNEGIE INSTITUTION OF WASHINGTON

In conformity with Article IV, section 2, of the By-Laws of the Carnegie Institution of Washington, the President has the honor to submit the following report on the work of the Institution for the fiscal year ending October 31, 1916, along with recommendations of appropriations for the ensuing year and with sundry suggestions concerning other matters of general or special interest.

This report is the fifteenth annual administrative report of the Institution and is presented under the following principal heads:

1. Historical notes.
2. Researches of the Institution.
3. Financial records.
4. Publications and bibliography.
5. Proposals for budget for 1917.

HISTORICAL NOTES.

Necrology.

It is the principal business of a research organization to observe and to investigate phenomena; but of the vast aggregate of phenomena presented to us by the universe only a few have been so clearly described that they may be said to be provisionally understood. In this vast aggregate there are, indeed, many which have been long observed but little investigated. Some of these, like bodily disease and social unwisdom, are plainly amenable to melioration; but there are others, quite as familiar, which have long baffled investigation and which seem destined to remain long in the elementary stage of observation alone. Amongst these latter the phenomenon of death is the most conspicuous and the least reconcilable. It prevails with a uniformity and a determinateness characteristic of the grander phenomena of the solar system and its average toll per unit time may be anticipated with a certainty little surpassed by the reckoning of the pro-

cession of the seasons. Thus, during the past year, the Institution has lost by death two Trustees, namely, William Nimick Frew and Seth Low, and a Research Associate, Professor Harry Clary Jones, of Johns Hopkins University.

Mr. Frew was a native of Pittsburgh. He was born there July 10, 1854, and died there October 28, 1915. His mature life was closely identified with the development of greater Pittsburgh, and his career in this civic work was in many respects similar to the remarkable career of Mr. Low in the development of Greater New York. Both men stood firmly for civic betterment and both aided conspicuously in securing the improvements in American municipal affairs of the past quarter of a century. Intimately associated with Mr. Carnegie in the establishment of the Carnegie Institute at Pittsburgh, Mr. Frew was the first President of its Board of Trustees and he served the Institute continuously in this capacity for about eighteen years. He was a member also of the Carnegie Hero Fund Commission, of the State Library Commission of Pennsylvania, and a Trustee of the Pennsylvania College for Women, as well as a Trustee of the Carnegie Institution of Washington since its foundation in 1902.

Seth Low was born at Brooklyn, New York, January 18, 1850, and he died at Bedford Hills, New York, September 17, 1916. His career and his constructive achievements constitute a well-known and highly esteemed national possession. For more than thirty years he has been recognized as one of the first citizens of the Republic. His contributions to civic righteousness, to education, and to altruistic enterprises generally have been of the first order. He has set an example worthy of emulation everywhere in the interests of sound business and efficient government. By inheritance a man of affairs and with exceptional opportunities for advancement in the commercial and industrial world, he devoted his time, his talents, and his energies almost wholly to the public weal. Probably no other man in the history of our country has done so much to raise the standard for, and to secure improvements in, municipal affairs. His two terms as Mayor of his native city and his term as Mayor of New York mark a noteworthy epoch in the evolution of reforms and improvements in American civic life. In these arduous

undertakings his altruism, his reasonableness, and his courage surmounted the most formidable obstacles.

Mr. Low was a Trustee of the Institution from the date of its foundation in 1902. He was a member of the Finance Committee from 1906 to 1914, and was its Chairman from 1909 to 1914. Although much preoccupied with many other affairs, in recent years especially, he maintained a keen interest in the development of the Institution, and he was ever ready to give freely of his friendly counsel drawn from an uncommonly rich and varied experience with men and with philanthropic organizations. He had great capacity for cooperation with heterogeneous groups of men and for the development of relations of reciprocity between such groups. The straightforwardness, the fairness, and the integrity shown by him in all such work will be long remembered by those with whom he was intimately associated.

Professor Harry Clary Jones, a Research Associate of the Institution since 1903, was born at New London, Frederick County, Maryland, November 11, 1865. He died at Baltimore, April 9, 1916. He was professor of physical chemistry in the Johns Hopkins University, of which he was a graduate and with which he was connected as student, instructor, and professor for about thirty years. Few contemporaries have been more enthusiastic and more indefatigable in research, and his untimely death may be not improbably ascribed to overwork. He was the author of ten volumes of reports of his researches published by the Institution. Sensitive, tireless, and possessing a keen sense of honor and responsibility, he devoted his life to the advancement of science with an energy and a fidelity worthy of the highest commendation.

Some salient events of the year.

The activities of the Institution are now so numerous and so varied that any item of progress of special interest to one group of individuals may be paralleled by other items of equal interest severally to other groups. Thus, "What at the moment are the most important investigations of the Institution?" is a question often asked but incapable of answer except with the proviso that since opinions differ the questioner is permitted to determine for himself, and

with the additional proviso that in so doing he is certain to entertain an inadequate estimate of the aggregate of these investigations. The items here cited, therefore, should be regarded as indicating the diversity of the Institution's work rather than as emphasizing any part of it.

Astronomy is at once the oldest and the most popular of the sciences. The immensity of the masses, the immensity of the distances asunder, and the majestic phenomena of the heavenly bodies appeal strongly to the imaginations of all classes of men; while the peculiar objectivity of astronomical studies has been of inestimable value in developing the reflective capacity of mankind. It seems safe to assert, indeed, that up to the present time astronomy has done more than all other sciences combined to assist man in learning how to orient himself aright in the universe of which he forms a relatively insignificant part but in which he plays the unique rôle of interpreter for his contemporaries and for his successors. It is no accidental circumstance, therefore, that the Institution should have given so much attention to the promotion of astronomical science, or that the Solar Observatory should have attracted so much popular interest. This interest has been enhanced during the past year by the essential completion of the 100-inch reflecting telescope. All of the serious difficulties of this great enterprise have been successfully overcome; and the parts of the instrument will doubtless be assembled for use during the coming year. The Solar Observatory will thus possess an unrivaled equipment for nearly all branches of stellar work except that of positional astronomy, to which the Institution is contributing substantial aid through its Department of Meridian Astrometry. It should be understood, however, that material equipment does not constitute an effective observatory. Much more important elements are to be found in the men who are able to design, to construct, and to use such equipment.

Of all the innumerable masses of the universe of interest to us the earth easily ranks first. It is the only one of these masses immediately accessible to us. It has served as a foundation for studies not only of the solar system but of the similar stellar systems, and it has given rise to many sciences, ranging from

geometry up to geophysics. Its dimensions, its mass, and its physical behavior are better known than those of any other body thus far observed by us. Hence nothing is more in the nature of things than that the Institution should support a Department of Terrestrial Magnetism and a Geophysical Laboratory; for although the subjects of research in these establishments lie on the borderlands of the older physical sciences, they demand separate treatment and elaborate equipment comparable in every way with the requirements of astronomy and geology. It was to meet one of the most important of such special needs that the non-magnetic ship, *Carnegie*, was constructed in conformity with specifications chiefly noteworthy by reason of the restrictions as to metals imposed by the Department of Terrestrial Magnetism. This vessel has proved remarkably successful and is now one of the best-known ships afloat As a direct aid to navigation she has already repaid her cost many times over, while the data she has accumulated will doubtless increase in value with the lapse of time. During the past year she has added an unexpectedly large mileage to her record. Starting from Dutch Harbor, Alaska, August 7, 1915, she arrived, after a continuous voyage, at Lyttelton, New Zealand, November 3, 1915. Leaving Lyttelton December 6, 1915, she sailed around the world (17,084 nautical miles) between the parallels of 50° and 60° south latitude, a voyage of only 118 days, during which complete observations of the magnetic elements were made on every day except one. Sailing again from Lyttelton May 17, 1916, she arrived at San Francisco September 21, 1916.

In the long run, a research establishment must be known largely, if not chiefly, by the published accounts of its investigations. For in so far as these are sound, and hence worth carrying on, they will be in general difficult of just appreciation and of immediate utilitarian application. The discoveries and advances of one generation are usually better understood and better utilized by succeeding generations. This is in accordance with the principle that while progress is generally due to individuals its advantages are chiefly for the race. Hence the prime importance of transmitting to our successors a trustworthy record of our methods, our theories, our achievements, and even of our errors and failures. One of the most effective means of fulfilling this

duty is found in the publication of books; for although these are destined to resolve themselves into the elements of which they are composed they will last long enough to enable our successors to extract from them all of the ideas worthy of further exposition and transmission. In illustration of this capital function of the Institution it seems fitting to call attention here to a few of the books issued by the Institution during the past year.

It was the counsel of one of the most learned men of the nineteenth century that those who wish their ideas to survive indefinitely should seek to express them in terms not subject to the vicissitudes of our planet. Although this counsel must evidently remain for a long time an unrealizable ideal in most domains of thought, an approximation to it has been attained in some of the older sciences. Thus, for example, the names of Euclid and Archimedes are likely to be transmitted undimmed into the far distant future for the compelling reason that they are linked to principles which must hold regardless of time and place. Similarly, the Greek astronomer Hipparchus will be well known ages hence, since he has connected his name indissolubly with the secular phenomena of the solar system by his discovery of the precession of the equinoxes and by his production of the first catalogue of stellar positions. This catalogue, known to the Greeks as the "Great Construction" (Μεγάλη Σύνταξις), was edited by Ptolemy, a worthy disciple of Hipparchus, and has come down to us finally (from A. D. 138) through several Greek, Latin, and Arabic editions as "Ptolemy's Almagest." And now, for the last time probably, the various editions of this remarkable work have been collated with a degree of thoroughness not hitherto attempted and a new edition of the catalogue has been issued during the year by the Institution. This edition is a result of the joint researches of the late Dr. C. H. F. Peters, astronomer of Hamilton College, and Mr. Edward B. Knobel, treasurer and past president of the Royal Astronomical Society of London. In addition to the profound historical importance of this early work, a great and permanent merit of this latest edition lies in the data it affords for fixation of the relative precision of the ancient determinations of stellar positions. Our admiration for the Alexandrian school of astronomers need not be diminished, however, by the fact that

the precision now attained in such determinations is incomparably superior to that attainable by the pioneers in this science twenty centuries ago.

Whatever may be our prepossessions or our reasoned convictions, those who have read Darwin's Origin of Species, or so much as the last paragraph thereof, must agree with him that "It is interesting to contemplate a tangled bank, clothed with many plants of many kinds, with birds singing on the bushes, with various insects flitting about, and with worms crawling through the damp earth, and to reflect that these elaborately constructed forms, so different from each other, and so dependent on each other in so complex a manner, have all been produced by laws acting around us." Even the unreflective farmer has noticed such tangled banks and has learned that noxious weeds will invade his fields and vanquish his crops if he is not duly vigilant. A considerable knowledge of biology, of plant, insect, and animal life is, indeed, now essential to successful economic husbandry; but although tradition has furnished a large aggregate of useful inductions for the needs of agriculture and horticulture, it is only in recent decades, dating substantially from the advent (1859) of Darwin's great work, that such inductions have begun to rise to the level of coordinated knowledge. It is in line with this general advance in biological science that the Department of Botanical Research finds reasons for its existence; and its activities accordingly have been devoted chiefly to investigations of the conditions of existence, the migrations, the mutations, etc., of species, families, and groups of plants, especially those characteristic of deserts. Naturally, this large domain for research has led to much division of labor and to much collaboration with many experts possessing special acquaintance severally with the numerous problems presented. During the past four years Dr. Frederic E. Clements, professor of botany in the University of Minnesota, has been attached to the Department as a Research Associate and has extended the field studies and elaborated the inductions on which he had been at work previously for many years. The results of his investigations are embodied in a remarkable book entitled "Plant Succession: An Analysis of the Development of Vegetation." This work extends the concepts of Darwin so vividly called to mind by the "tangled bank"

and views the successive plant-complexes which invade any region as so many organic units, each enacting its rôle no less definitely than is enacted the rôle of an individual plant or other organism. This work of Professor Clements brings the relatively new science of ecology and paleo-ecology prominently forward. It is a profoundly instructive book also by reason of the analogies it suggests, especially to the student of contemporary events, between the struggle for existence of the lower species and the struggle for existence of the highest species in the biological world.

In further indication of the diversity, if not the catholicity, of the Institution's activities, it is worthy of mention in this connection that Dr. H. Oskar Sommer's edition of the Vulgate Version of the Arthurian Romances has been completed during the year by the publication of an eighth volume giving an index to names and places of the preceding volumes; that a concordance to Spenser, edited by Professor Charles G. Osgood, and a concordance to the poet Horace, edited by Professor Lane Cooper, have been issued, while a concordance to the poems of Keats is in press; and that a new edition of "The Old Yellow Book" (Source of Browning's "The Ring and the Book") has been reproduced and is now ready to meet the legitimate demand which has exhausted the supply of the first edition published eight years ago. Special progress has been made likewise in the publication of the series of "Classics of International Law," issued by the Institution under the editorship of Professor James Brown Scott, the works of Vattel, Rachel, and Textor, eight volumes in all, having appeared.

It is a noteworthy fact, illustrating the fallibility of offhand opinions and unreasoned predictions, that "The Old Yellow Book," Professor Boss's Star Catalogue (reproduced photographically in 1915), Dr. Erwin F. Smith's work on bacteriology, and Dr. F. E. Wright's exposition of methods of research in petrography have proved to be the publications of the Institution thus far most in demand, if we may judge by the public willingness to purchase them at the nominal prices for which they are offered for sale. It is believed that this willingness to purchase at the cost of production affords the best objective measure of the merits of these works; for although some might hold that "The Old Yellow Book" appeals to the unworthy as well as to the higher

motives of mankind, there is no room for any such hypothesis in respect to a star catalogue or in respect to the principles of microscopic-petrography.

Public estimation of research.

Numerous references have been made in preceding reports to the growing realization of the world at large that the methods of science are the most effective methods thus far developed for the advancement of learning and for the mitigation of the consequences of the inexorable "laws of nature" which condition existence on our planet. Reference has been made likewise to the contemporary rise and progress of other research establishments and to the introduction of investigation as an economic adjunct to industrial enterprises. These manifestations of popular approval and confidence continue to be among the most noteworthy signs of the times. Indeed, it is plain that we are now witnessing a remarkably rapid evolution of public understanding of the meaning and the value of research. This has been greatly intensified and accelerated by the European war, whose sinister aspects appear to be relieved in some degree by the prospects of an awakened realization of the availability of better methods than those of warfare for settling international disputes, of better methods than those now commonly applied in the government of states, and of better methods in education, in sanitation, in industry, and in biological economy generally. The European war has emphasized to a degree not hitherto attained in the world's history the perils of ignorance, of government by assumed divine right, and of that sort of diplomacy which shades off by insensible degrees into duplicity; and it has emphasized equally clearly the necessity for rational investigation of and progressive reforms in all national affairs.

How the details of this evolution, in which the Institution must participate, will work themselves out is impossible to predict except in general terms. It may be safely inferred, however, from the history of similar developments, that this one will proceed much more slowly and with much more difficulty than many enthusiastic optimists anticipate. Evolution is, in general, a secular process and goes on with a leisurely disregard of individuals. It may be safely inferred also that many of the numerous

fallacies which have beset the Institution during the brief interval of its existence will recur again and again in the rise of similar organizations, while fallacies of a more troublesome type are likely to beset the introduction of the methods and the results of research in governmental affairs. It is in the latter affairs that the most stubborn opposition to progress is usually met, since there exist, as a rule, in such affairs no adequately developed relations of reciprocity between those best qualified to suggest and to formulate improvements and those who control the machinery for their applications. Such improvements can be secured only by overcoming a stolid adherence to precedent as well as the reluctance of rational conservatism. Thus it happens in governmental affairs that the most incongruous ideas often coexist, as is well shown by the contemporary adoption of the most advanced principles of sanitation in certain European countries which are still dominated by medieval theories of the functions of a state. To cite another illustration readily understood and verifiable, it is an anomalous fact that the United States Government exacts no professional requirements for the direction of its highly technical affairs except in a single branch of its service, namely, the legal. And in line with this glaring national deficiency it is notorious that the fiat of an executive can make an astronomer, a geodesist, or a biologist out of a man whose works are unknown in the annals of the science of which he becomes the ex-officio representative. We hear much also in these days of the "mobilization of genius" in the interests of national preparedness for commercial and industrial competition, if not for the more serious exigencies of national defense; but it is to be feared that this mobilization means fruitless attempts to utilize aberrant types of mind, or perhaps the employment of men of talent under the direction of those whose competency for leadership is admitted, if at all, only in quite other fields of activity than those here considered. In the meantime, it is plain enough, in the light of current events, that any nation whose governors mistake necromancy for science, confound invention with investigation, or fail to utilize effectively available and advancing knowledge, is in danger of humiliation in peaceful international competition if not in danger of extinction in international conflict.

RESEARCHES OF THE INSTITUTION.

Much, perhaps too much, has been said in preceding reports concerning the maxims and the principles which should be observed on the administrative side in the conduct of research. To a great extent these maxims and principles are the same as those developed in the common experience of the race; but to a greater extent they are derived from the more concrete and the more sharply defined experience developed in the evolution of the older sciences. All experience teaches that effective research depends on painstaking labor, arduously, patiently and persistently applied; while all science teaches that research is effective only in those regions wherein something like demonstration can be attained. If investigations can not be well done they are of little worth; if nothing can be proved they are of still less worth, or at best only of negative value. But obvious as these truisms are when stated by themselves, they have been contradicted daily in the plexus of events which make up what our successors will call the history, recorded and unrecorded, of the Institution. Thus it has been suggested not infrequently that promising researches be suspended in order that equally or less promising researches might be taken up; and it has happened that proposals to abolish departments of research have been seriously advanced before these departments have had time to prove their rights to existence. It is not infrequently suggested, likewise, by otherwise irreproachable correspondents, that the experts of the laboratories and observatories of the Institution be set at work under the direction of amateurs, or, in some cases, of those even who have not reached that earliest stage of capacity in science.

Conditions of procedure.

It goes without saying that all such untoward influences should have little effect on the rise and progress of a research establishment; but he would be an incompetent administrator who failed to recognize the existence and the dangers of these influences. Most men are still opportunists; many contemn principles and theories of procedure; while the characteristic defect of deliberative bodies, strikingly illustrated by legislative assemblies, is lack of deliberation. Moreover, what any organization, altruistic or otherwise, may accomplish at any epoch, or during any period,

will depend very largely on the status of contemporary public opinion. No organization may be rationally expected to rise much above the level of the ideals of those who support and direct it. The law of averages and the "law of conservation of ignorance" apply in the business of research no less rigorously than in other affairs of human endeavor. The only difference is that in research, from the nature of the case, we are held to stricter accountability; it is incumbent on us to be alive to the ideals and the theories which lead to regress as well as alive to the ideals and the theories which lead to progress.

Departments of research.

Although popular opinion continues to look upon the Institution as an establishment of unlimited means, and hence of unlimited capacities, it is an easily ascertained fact that such advances as have been attained are due chiefly to concentration of effort in a few fields of investigation, the number of these being necessarily limited by the finiteness of income. Of the agencies which have contributed most to these advances the departments of research must be given first rank when quality and quantity of results accomplished are taken into account. These departments have supplied also a much needed verification of the axiom hitherto admitted in all domains of activity except those of research, namely, that if any good work is required the best way to get it done is to commit it to competent men not otherwise preoccupied. They have verified, likewise, the equally obvious truth that large and difficult undertakings demand foresight and oversight, prolonged effort, and a corresponding continuity of support. The idea that discoveries and advances are of meteoric origin and that they are due chiefly to abnormal minds has been rudely shattered by the remorseless experience of the Institution.

Along with these considerations special mention should be made of another of vital importance to the departments of research. This is their complete autonomy within the limits of their annual appropriations. Allusion is made to this matter here partly for the purpose of correcting public misapprehension concerning the relations of these departments to the Institution as a whole, and partly for the purpose of stating formally the theory of administration followed by the Institution during the past twelve years. Such a degree of freedom accorded to the

departments of research is not only necessary by reason of the extent and the complexity of the affairs of the Institution, but it should be regarded as a fundamental principle of sound administration. No one can follow the details of all these varied affairs. A division of labors is indispensable, and to the greatest extent practicable the director of a department of research should be encouraged to be the autocrat of his departmental destiny. But in so far as departments are granted liberty of action it is an equally fundamental principle of administration that they should assume corresponding responsibilities. Autonomous freedom and reciprocal accountability are then, in brief, the essentials of the theory under which the departments of research have evolved.

Reports of Departments.

In consonance with the theory just indicated and in conformity with the precedent set a year ago, no attempt is made here to furnish abstracts of the current departmental reports. They give sufficiently condensed summaries of departmental activities and departmental progress. They are, as a rule, highly technical papers and difficult of adequate appreciation even by those somewhat familiar with the subjects considered. But this is not only just as it should be, but it is inevitable if the investigations under way are worth making. Our confidence in them must be founded in large degree on the general principles revealed in the advancement of science. Great and admirable achievements were attained by the ancients prior to the epoch of recorded history; still greater achievements were attained by the Greeks, the Arabs, and the moderns down to the epoch of Galileo and Newton; while competent judges have estimated that greater progress was secured in the nineteenth century than during all previous history. It is quite within conservative reason, therefore, to assume that if we continue to follow those principles, now grounded in more than twenty centuries of repeatedly verified experience, in the light of accumulated and recorded knowledge, we may confidently expect to achieve corresponding further advances.

The question is sometimes raised as to how the efficiencies of investigators and of departments of research are, or possibly may be, estimated. Occasionally, also, there seems to be entertained along with this question the hypothesis that research is a

commodity and that money is the chief agent in promoting its effective increase. But the currently common meaning of efficiency implied in this question and in this hypothesis is too narrow for application here. It applies rather to machines and to aggregates of men working like machinery for predetermined economic ends. In a broader sense, however, the question of efficiency of men and of organizations is worthy of considerate attention. It is, indeed, in this inclusive sense, a question of the greatest importance, especially in all cooperative enterprises of communities and states. But without going into these larger aspects of the matter, it may be said that the efficiencies of the investigators and of the departments of research of the Institution are determined in the same way that justification for the Institution as a whole is determined, namely, by the consensus of competent opinion. In science, the work of an individual is measured on its merits and the work of an organization is weighed in the same manner. Adequate tests and standards for what is not fully known may not be wisely set up in acts of administration. Severer tests and higher standards are supplied automatically and relentlessly by contemporary criticism and by the verdicts of posterity. Hence, given a corps of trained investigators, or an organization of several such, the question of efficiency is happily one which is decided for us mainly by those who are alone qualified to render adequate judgment.

Research Associates.

Like all other branches of the Institution, the Division of Research Associates has undergone a distinct evolution. Originally a division which gave rise to excessive and often unrealizable expectations, it has gradually become shorn of its extrinsic appendages and divested of its inheritances from occultism. In spite of these omnipresent obstacles to progress and to efficiency, this division has been highly productive from the beginning and continues to be one of the most important agencies of the Institution for the promotion of learning. The main reason for the noteworthy success of this agency is very simple. It was stated in a recommendation concerning research associateships, in the report of the President for the year 1906, in these words: "The limitation of eligibility for such positions to investigators of proved capacity for and of proved opportunity for research." In the meantime,

the number of those possessing such qualifications has increased much more rapidly than the resources of the Institution (or than the resources of all research agencies combined) have increased to meet this and other growing financial needs. Not only has income failed to keep pace with worthy demands, but, as repeatedly pointed out hitherto, the purchasing capacity of income has steadily declined since the foundation of the Institution. Thus it happens that now, just as the merits of the system of Research Associates have come to be generally recognized, it is essential to suspend extension of this system, and it may become essential to curtail to some extent the amounts of the grants hitherto made to those who have helped most to develop this remarkably effective division of the Institution's activities.

It should be evident from the preceding paragraphs of this section of the report, as well as from numerous passages in previous reports, that the income of the Institution is not only not equal to popular estimates, but that it is not equal even to the legitimate demands on it for research. This proposition is easily verified, although few people believe it and fewer still are willing to undertake the small arithmetical labor essential for its demonstration. On the other hand, it is admitted by everybody that the Institution is not doing as much as it could, but the simple reasons for this obvious fact appear to be far from equally obvious. Whether it would be desirable, if practicable, to double, say, the endowment, and hence the income, of the Institution is a question well worthy of consideration. But along with many reasons why it would be so desirable there might be adduced also many other reasons why it would not. This is, indeed, a fundamental question whose deliberate consideration should precede the next step. We possess as yet no well-defined and generally accepted theory of a research organization. The Institution, plainly enough, stands somewhat in isolation. It would prosper better, probably, and be better understood, certainly, if it had more contemporaries with which to divide not only the vast fields of opportunity, but also the vast aggregate of fruitless labors imposed on those who should be preoccupied with the business of research. In the meantime, while no expansion is permissible under existing income, the current activities of the Institution may continue without serious modification of plans or impairment of efficiency.

FINANCIAL RECORDS.

Financial Statement for Fiscal Year 1915-1916.

The sources of funds available for expenditure during the past fiscal year, the allotments for the year, the revertments made during the year, and the balances unallotted at the end of the year are shown in detail in the following statement:

Object of appropriation.	Balances unallotted Oct. 30, 1915.	Appropriation Dec. 11, 1915.	Revertments Nov. 1, 1915, to Oct. 31, 1916.	Total.	Aggregates of allotments and amounts transferred.	Balances unallotted Oct. 31, 1916.
Large grants.	....	$654,736.00	......	$654,736.00	$654,736.00	....
Minor grants..	2,445.18	116,832.18	552.58	119,829.94	115,974.74	$3,855.20
Publication....	7,394 75	60,000.00	6,888.42	74,283.17	59,026.40	15,256.77
Administration.	...	50,000.00	.....	50,000.00	50,000.00	....
Reserve fund...	....	250,000.00	.....	250,000.00	250,000.00	....
Insurance fund..	....	25,000.00	....	25,000.00	25,000.00	....
Total...	9,839.93	1,156,568.18	7,441.00	1,173,849.11	1,154,737.14	19,111.97

The aggregates of receipts from interest on endowment, from interests on bond investments, from interest on deposits in banks, from sales of publications, from refunds on grants, and from miscellaneous sources, for each year since the foundation of the Institution, are shown by the following table; the grand total of these to date is $13,007,733.03.

Summary of Receipts and Expenditures of the Institution to date.

Aggregates of financial receipts.

Year ending Oct. 31.	Interest on endowment.	Interest on bonds and bank deposits.	Sales of publications	Refund on grants.	Miscellaneous items.	Total.
1902	$250,000.00	$9.70	....	....	$1,825.52	$251,835.22
1903..	500,000 00	5,867.10	$2,286.16	....	101.57	508,254.83
1904	500,000 00	33,004.26	2,436 07	$999.03	....	536,439.36
1905..	500,000.00	25,698.59	3,038.95	200.94	150.00	529,088.48
1906..	500,000 00	27,304.47	4,349 68	2,395.25	19.44	534,068.84
1907.	500,000 00	22,934.05	6,026.10	2,708.56	15.22	531,683.93
1908 .	550,000 00	17,761 55	7,877 51	25.68	48,034.14	623,698.88
1909	600,000.00	14,707.67	11,182.07	2,351.48	103,564.92	731,806.14
1910	600,000.00	10,422.78	10,470.25	1,319.29	54,732.45	676,944.73
1911.	975,000.00	14,517.63	10,892.26	4,236.87	923.16	1,005,569.97
1912..	1,100,000.00	31,118.41	11,496.13	1,658.88	96,035.01	1,240,308.42
1913	1,103,355 00	46,315.60	12,208.66	3,227.53	345,769.95	1,510,876.74
1914	1,105,084.17	59,298.63	11,402.40	7,819.70	577,305.77	1,760,910.67
1915	1,100,375.00	67,888.31	10,297 79	8,322.87	28,162.79	1,215,046.76
1916.	1,100,375.00	83,626.38	12,544.16	1,450.12	153,204.40	1,351,200.06
Total.	10,984,189.17	460,475.13	116,508.19	36,716.20	*1,409,844.34	13,007,733.03

*Of this amount $1,341,500 came from the sale of bonds in 1908, 1909, 1910, 1912, 1913, 1914, 1915, 1916, also $51,265.74 from Colburn Estate in 1916

The purposes for which funds have been appropriated by the Board of Trustees of the Institution may be summarily classified under five heads: (1) investments in bonds; (2) large projects; (3) minor projects, special projects, and research associates and assistants; (4) publications; (5) administration. The following table shows the actual expenditures under these heads for each year since the foundation of the Institution:

Purposes for which funds have been appropriated.

Year ending Oct. 31.	Investments in bonds.	Large projects.	Minor projects, special projects, research associates, and assistants.	Publications.	Administration.	Total.
1902...	....	....	$4,500 00	..	$27,513 00	$32,013.00
1903..	$100,475 00	....	137,564.17	$938 53	43,627 66	282,605.36
1904.	196,159.72	$49,848 46	217,383.73	11,590 82	36,967.15	511,949.88
1905..	51,937.50	269,940.79	149,843 55	21,822 97	37,208.92	530,753.73
1906..	63,015 09	381,972 37	93,176 26	42,431 19	42,621 89	623,216.80
1907..	2,000 00	500,548.58	90,176 14	63,804 42	46,005.25	702,534.39
1908..	68,209 80	448,404 65	61,282 11	49,991.55	48,274.90	676,163.01
1909...	116,756 26	495,021.30	70,813 69	41,577.48	45,292.21	769,460.94
1910 .	57,889 15	437,941 40	73,464.63	49,067 00	44,011 61	662,373.79
1911...	51,921 79	463,609 75	63,048.80	37,580 17	45,455 80	661,616.31
1912..	436,276 03	519,673 94	103,241.73	44,054 80	43,791 13	1,147,037.63
1913..	666,428 03	698,337 03	110,083 06	53,171.59	43,552.89	1,571,572.60
1914 ..	861,915 73	817,894.52	107,456 05	44,670 55	44,159 54	1,876,096.39
1915 .	206,203 21	770,488.58	109,569 37	46,698 56	48,224 04	1,181,183.76
1916 .	473,702 70	638,281.41	99,401 26	73,733 38	49,454 08	1,334,572 83
Total	3,352,890 01	6,491,962 78	1,491,004 55	581,133 01	646,160 07	12,563,150.42

The following list shows the departments of investigation to which the larger grants were made by the Trustees at their last annual meeting and the amounts allotted from these grants by the Executive Committee during the year:

Department of Botanical Research........................	$38,480
Department of Economics and Sociology.....	
Department of Embryology................................	30,420
Department of Experimental Evolution........................	50,411
Geophysical Laboratory...............................	85,000
Department of Historical Research........................	28,900
Department of Marine Biology..............................	17,150
Department of Meridian Astrometry	26,860
Nutrition Laboratory................................	42,930
Division of Publications................................	10,500
Solar Observatory................................	192,319
Department of Terrestrial Magnetism	131,766
Total................................	654,736

The following statements show the fields of investigation to which minor grants were assigned, together with the names of the grantees and the amounts of the grants; also the grants for publications authorized during the year; and the sources and amounts of revertments from November 1, 1915, to October 31, 1916.

Details of minor grants.

Fields of investigation.	Names of grantees.	Amounts of grants.
Astronomy	Kapteyn, J. C.	$2,000.00
Archeology	Van Deman, E. B.	2,100 00
	Morley, S. G.	8,429.00
Bibliography	Index Medicus	12,000.00
Biology	Department of Experimental Evolution	300.00
	Morgan, T. H.	3,300 00
	Vaughan, T. W.	300.00
Botany	Britton, N. L., and J N. Rose	7,550.00
Chemistry	Jones, H. C.	2,037.69
	Morse, H. N	4,000 00
	Noyes, A. A	1,800.00
	Osborne, T. B., and L. B. Mendel	15,000 00
	Richards, T. W.	2,700 00
	Sherman, H. C	1,080.00
Geology	Chamberlin, T. C	1,100 00
	Moulton, F. R	1,800.00
History	Osgood, H. L	1,800 00
Literature	Bergen, Henry	1,800 00
Mathematics	Morley, Frank.	1,200 00
Meteorology	Bjerknes, V	1,800 00
Paleontology	Case, E. C	1,500.00
	Hay, O. P	3,000.00
	Wieland, G. R.	3,000.00
Philology	Churchill, William	5,085 00
	Loew, E. A	2,100 00
	Tatlock, John S. P	300.00
Physics	Barus, Carl	500 00
	Hayford, J. F	1,800.00
	Nichols, E. L.	3,000 00
Zoology	Castle, W. E	2,500 00
Administration Building		270 00
Reception, Second Pan-American Scientific Congress		823 05
		95,974.74

Grants for publications authorized during the year.

Barnard, E. E	$5,000.00
Barus, Carl	1,200.00
Boss, Benjamin, *et al.*	2,000.00
Carnegie Institution of Washington Pamphlets	600.00
Castle, W. E., and S. Wright	1,477.49
Churchill, William	1,600.00
Clements, F. E.	4,400.00
Contributions to Embryology	2,000.00
Do	3,800.00
Cooper, Lane	1,773.09
Estabrook, A. H	1,560.44
Golder, Frank A	900.00
Goodale, H. D	1,200.00
Index to State Documents	5,000.00
Ivens, W. G	1,600.00
Knobel, E. B	1,300.00
Meyer, B. H	3,000 00
Osgood, C. G	3,548 43
Republication of Classics of International Law	10,000.00
Researches, Department of Terrestrial Magnetism	4,000.00
Sommer, H. O	880.58
Stager, Henry W	186.37
Weed, L. H.	2,000.00
	59,026 40

Sources and amounts of revertments from Nov. 1, 1915, to Oct. 31, 1916.

Minor grants:		
Panama-Pacific International Exposition, Grant No. 945		$552.58
Publications:		
Contributions to Embryology, Grants Nos. 1023, 1035, 1039	$10.12	
Shreve, Forrest, Grant No. 1032	303.80	
Barus, Carl, Grant No. 1043	691.25	
Benedict, F. G., and F. B. Talbot, Grant No. 1049	286 78	
Johnson, E. R., *et al.*, Grant No. 1038	335 39	
Star Catalogue, Reprint, Grant No. 1048	95.90	
Davenport, C. B., Grant No. 1047	679.13	
Dodge, R., and F. G. Benedict, Grant No. 1041	202.03	
Johnson, D. S., and H. H. York, Grant No. 1004	969.77	
Peters, C. H. F., and E. B. Knobel, Grants Nos. 930, 969	105.41	
Clark, V. S., Grant No 1050	92.93	
Faust, A. B. Grant No. 1044	99 42	
Morgan, T. H., and C. B. Bridges, Grant No. 1052	424.21	
Moodie, R. L., Grant No. 1053	286.22	
Wieland, G. R., Grant No. 1033	1,132.60	
Clements, F. E., Grant No. 1088	1,173.46	
		6,888.42
		7,441.00

Amounts of transfers from November 1, 1915, to October 31, 1916.

Administration to unappropriated fund	$5,000	
Minor grants to unappropriated fund	20,000	
		$25,000

Investments in Property. On account of site for and construction of the Administration Building of the Institution, and on account of real estate, buildings, and equipments of departmental establishments, the following sums have been expended:

Expenditures since organization on account of real estate, equipments, and publications.

Administration:		
Building. site, and equipment		$332,791.12
Publications:		
Stock on hand (Oct. 31, 1916)	$259,290.10	
Outstanding accounts (Oct. 31, 1916)	2,572.65	
		261,862.75
Department of Botanical Research (Sept. 30, 1916):		
Buildings, office, and operating	51,650.51	
Laboratory equipment	13,029.06	
		64,679.57
Department of Experimental Evolution (Sept. 30, 1916):		
Buildings, office, and library	109,538.65	
Laboratory apparatus	8,054.60	
Operating appliances and grounds	21,162.08	
		138,755 33
Geophysical Laboratory (Sept. 30, 1916):		
Building, library, operating appliances	164,403.57	
Laboratory apparatus	64,971 26	
Shop equipment	10,144.16	
		239,518.99
Department of Historical Research (Sept. 30, 1916):		
Office	2,131.93	
Library	3,034.09	
		5,166 02
Department of Marine Biology (Sept. 30, 1916):		
Vessels	32,944.40	
Buildings, docks, furniture, and library	11,967.96	
Apparatus and instruments	5,543.12	
		50,455.48
Department of Meridian Astrometry (Sept. 30, 1916):		
Apparatus and instruments	2,394.34	
Operating	1,277.62	
		3,671.96
Nutrition Laboratory (Sept. 30, 1916):		
Building, office, and shop	117,636.35	
Laboratory apparatus	22,442.39	
		140,078.74
Mount Wilson Solar Observatory (Aug. 31, 1916):		
Buildings, grounds, road, and telephone line	196,193.06	
Shop equipment	37,144.26	
Instruments	405,595.94	
Furniture and operating appliances	85,483 03	
Hooker 100-inch reflector	453,973.86	
		1,178,390.15
Department of Terrestrial Magnetism (Sept. 30, 1916):		
Building, site, and office	131,319.00	
Vessel and survey equipment	125,897.69	
Instruments, laboratory, and shop equipment	59,932 52	
		317,149 21
		2,732,519.32

Expenses of Maintenance of Administration Building.

The cost of maintenance of the Administration Building, including the items of fuel, lighting, janitorial services, maintenance of grounds, repairs, and other incidental expenses, has been, for 1910, $2,981.65; for 1911, $2,641.53; for 1912, $2,919.89; for 1913, $2,601.15; for 1914, $3,251.08; for 1915,* $3,955.60; and for 1916, 2,870.51.

*Includes unusual expenses incident to the examination and repointing of the masonry joints of the building and to the installation of an overhead water-supply system.

PUBLICATIONS.

Publications Authorized and Issued during the Year.

The publication of 23 volumes has been authorized by the Executive Committee during the year, at an aggregate estimated cost of $59,026.40. The following list gives the titles and names of the authors of the publications issued during the year; it includes 35 volumes, with an aggregate of 9,478 octavo pages and 2,430 quarto pages; 24 additional volumes are now in press.

List of publications issued during the year.

Year Book, No. 14, 1915. Octavo, 441 pages, 3 plates, 4 figures.

Index Medicus, Second Series, vol 13, 1915. Octavo, 1011+II+170 pages.

No. 34. Wieland, G. R. American Fossil Cycads. Vol. II. Taxonomy. Quarto, VII+277 pages, 58 plates, 97 text figures.

No. 74. Sommer, H. Oskar. Vulgate Version of the Arthurian Romances, edited from manuscripts in the British Museum. Index of Names and Places. Quarto, 85 pages.

No. 86. Peters, C. H. F., and E. B. Knobel. Ptolemy's Catalogue of Stars: A Revision of the Almagest. Quarto, III+207 pages.

No. 89. Hodell, Charles W. The Old Yellow Book: Source of Browning's "The Ring and the Book." Reprint. Octavo, 7+CCLXII+345 pages, 4 plates.

No. 115. Boss, Lewis. Preliminary General Catalogue of 6188 Stars for the Epoch 1900, including those Visible to the Naked Eye and other well-determined Stars. Second Edition. Photographic Reproduction. Quarto, 3+XXXVII+345 pages.

No. 151. Stager, Henry W. A Sylow Factor Table of the First Twelve Thousand Numbers, giving the Possible Number of Sylow Sub-Groups of a Group of Given Order between the Limits of 0 and 12,000. Quarto, XII+120 pages, 1 plate.

No. 189. Osgood, C. G. A Concordance to the Poems of Spenser. Quarto, XIII+997 pages, 1 plate.

No. 202. Cooper, Lane. A Concordance to the Works of Horace. Octavo, X+593 pages.

No. 206. Johnson, Duncan S., and Harlan H. York. The Relation of Plants to Tide Levels: A Study of Factors affecting the Distribution of Marine Plants. Octavo, 162 pages, 24 plates, 5 figures.

No. 215A. Johnson, E. R., T. W. Van Metre, G. G. Huebner, and D. S. Hanchett, with an introductory note by H. W. Farnam. History of Domestic and Foreign Commerce of the United States. Octavo. Vol. I. XV+363 pages, maps 1 to 5. Vol. II. IX+398 pages, maps 6 to 10.

No. 215B. Clark, Victor S. History of Manufactures in the United States, 1607 to 1860. Octavo, XII+675 pages, 7 plates, and 7 text-figures.

No. 220. Faust, A. B. Guide to Materials for American History in Swiss and Austrian Archives. Octavo, X+229 pages.

No. 229. Barus, Carl. Experiments with the Displacement Interferometer. Octavo, VI+113 pages, 66 figures.

No. 232. Dodge, Raymond, and F. G. Benedict. The Psychological Effects of Alcohol. An Experimental Investigation of the Effects of Moderate Doses of Ethyl Alcohol on a Related Group of Neuro-muscular Processes in Man. Octavo, 281 pages, 1 plate, 32 figures.

No. 233. Benedict, Francis G., and Fritz B. Talbot. The Physiology of the New-born Infant: Character and Amount of the Katabolism. Octavo, 126 pages, 10 figures.

No. 236. Davenport, C. B. The Feebly Inhibited: Nomadism or the Wandering Impulse, with Special Reference to Heredity. Inheritance of Temperament. (Paper No. 24, Station for Experimental Evolution.) Octavo, 158 pages, 89 figures.

No. 237. Morgan, T. H., and C. B. Bridges. Sex-linked Inheritance in Drosophila. Octavo, 87 pages, 2 plates, 8 figures.

No 238. Moodie, Roy Lee. The Coal Measures Amphibia of North America. Quarto, X+222 pages, 26 plates, 43 text-figures.

No. 240. Estabrook, A. H. The Jukes in 1915. (Paper No. 25, Station for Experimental Evolution.) Quarto, VII+85 pages, 28 charts.

No. 241. Castle, W. E., and Sewall Wright. Studies in Inheritance in Guinea-Pigs and Rats. (Paper No. 26, Station for Experimental Evolution.) Octavo, IV+192 pages, 7 plates, 7 text-figures.
An Expedition to the Home of the Guinea-Pig and some Breeding Experiments with Material there obtained. By W. E. Castle. Pages 1 to 55.
An Intensive Study of the Inheritance of Color and of Coat Characters in Guinea-Pigs, with especial reference to Graded Variations. By Sewall Wright. Pages 57 to 160.
Further Studies of Piebald Rats and Selection, with Observations on Gametic Coupling. By W. E. Castle. Pages 161 to 192.
No. 242. Clements, Frederic E. Plant Succession: An Analysis of the Development of Vegetation. Octavo, XIII+512 pages, 61 plates, 50 figures.
No. 243. Goodale, H. D. Gonadectomy in relation to the Secondary Sexual Characters of Some Domestic Birds. (Paper No. 27, Station for Experimental Evolution.) Octavo, 52 pages, 7 plates.
No. 244. Churchill, William. Sissano: Movements of Migration within and through Melanesia. Octavo, 181 pages, 17 charts.
No. 249. Barus, Carl. The Interferometry of Reversed and Non-reversed Spectra. Octavo, 158 pages, 21 tables, 99 figures.
Illustrated pamphlet descriptive of the plan and scope of the Institution. Fifth edition, dated September 1, 1916. Octavo, 51 pages.
Classics of International Law:
Vattel, E. de: Le Droit des Gens.
Vol. I. A Photographic Reproduction of Books I and II of the First Edition (1758), with an Introduction by A. de Lapradelle. Octavo, LIX+541 pages, and portrait of Vattel.
Vol. II. A Photographic Reproduction of Books III and IV of the First Edition (1758). Octavo, XXIV+376 pages.
Vol. III. Translation of the Edition of 1758 (by Charles G. Fenwick), with translation (by G. D. Gregory) of Introduction by A. de Lapradelle. Octavo, LXXXVIII+398 pages.
Rachel, Samuel: De Jure Naturae et Gentium Dissertationes. Introduction by L. von Bar.
Vol. I. A Reproduction of the Edition of 1676, with portrait of Rachel. Introduction by Ludwig von Bar, and List of Errata. Octavo, 16a+x+335 pages.
Vol. II. A Translation of the Text, by John Pawley Bate, with Index of Authors Cited. Octavo, 16a+IV+233.
Textor, Johann Wolfgang: Synopsis Juris Gentium. With introduction by Ludwig von Bar.
Vol. I. A Reproduction of the First Edition (1680), with portrait of Textor. Introduction by Ludwig von Bar, and List of Errata. Octavo, 28a+VI+148+168 pages.
Vol. II. A Translation of the Text, by John Pawley Bate, with Index of Authors Cited. Octavo, 26A+V+349 pages.

Sales of Publications and Value of those on hand.

The following table shows the amounts received from subscriptions to the Index Medicus, from sales of Year Books, and from sales of all other publications for each year since the foundation of the Institution:

Table showing sales of publications.

Year.	Index Medicus.	Year Book.	Miscellaneous books.
1903	$2,256 91	$29 25	. . . . .
1904	2,370 47	52.85	$12.75
1905	2,562 76	44 75	431 44
1906	2,970.56	37.60	1,341 52
1907	3,676 71	56.50	2,292.89
1908	3,406 19	99 65	4,371.67
1909	4,821.85	73.01	6,287.21
1910	4,470 50	100.70	5,899 05
1911	4,440.21	85 50	6,366.55
1912	4,652.14	61 65	6,782.34
1913	4,992.02	75.95	7,140.69
1914	5,079 16	49.65	6,273.59
1915	5,010 21	47.60	5,239.98
1916	4,382.19	46.60	8,115.37
Total...	55,091 88	861.26	60,555.05

At the end of the fiscal year there are on hand 100,128 volumes of miscellaneous publications and Year Books, having a sale value of $243,142.35; also 31,081 numbers of the Index Medicus, having a sale value of $16,147.75. The total value of publications on hand is therefore $259,290.10.

In connection with the above statement it is fitting to add that since the foundation of the Institution there have been distributed, chiefly by gifts to libraries and to authors, but to a noteworthy extent also by sales, a total of 159,908 volumes of publications of the Institution.

Growth and Extent of Institution's Publications.

The data furnished in the following table are of statistical interest in respect to the work of publication of the Institution. Three hundred and thirty-four volumes, embracing a total of more than 91,000 pages of printed matter, have thus far been issued by the Institution.

Table showing number of volumes, number of pages (octavo and quarto), and totals of pages of publications issued by the Institution for each year and for the fourteen years from 1902 to 1916.

Year.	Number of volumes issued.	Number of octavo pages.	Number of quarto pages.	Total number of pages
1902	3	46		46
1903	3	1,667		1,667
1904	11	2,843	34	2,877
1905	21	3,783	1,445	5,228
1906	19	3,166	1,288	4,454
1907	38	6,284	3,428	9,712
1908	28	4,843	2,485	7,328
1909	19	3,695	1,212	4,907
1910	29	3,274	4,831	8,105
1911	30	5,062	1,670	6,732
1912	23	3,981	2,044	6,025
1913	29	6,605	2,752	9,357
1914	23	4,978	1,934	6,912
1915	23	4,686	1,466	6,152
1916	35	9,478	2,430	11,908
Total	334	64,391	27,019	91,410

APPENDIX.

BIBLIOGRAPHY OF PUBLICATIONS RELATING TO WORK OF INVESTIGATORS, ASSOCIATES, AND COLLABORATORS.

Under this heading it is sought to include titles of all publications proceeding from work done under the auspices of the Carnegie Institution of Washington, exclusive of the regular publications. A list of the latter which have appeared during the year will be found in the President's Report (pp. 23, 24).

ADAMS, L. H. See JOHNSTON, JOHN.

ADAMS, WALTER S. Investigations in stellar spectroscopy: I. A quantitative method of classifying stellar spectra. Proc. Nat. Acad. Sci., vol. 2, 143 (1916); Mt. Wilson Communications, No. 23.

———. Investigations in stellar spectroscopy: II. A spectroscopic method of determining stellar parallaxes. Proc. Nat. Acad. Sci., vol. 2, 147 (1916); Mt Wilson Communications, No. 24.

———. Investigations in stellar spectroscopy: III. Application of a spectroscopic method of determining stellar distances to stars of measured parallax. Proc. Nat. Acad. Sci., vol. 2, 152 (1916); Mt. Wilson Communications, No. 25.

———. Investigations in stellar spectroscopy: IV. Spectroscopic evidence for the existence of two classes of M-type stars. Proc. Nat. Acad. Sci., vol. 2, 157 (1916); Mt. Wilson Communications, No. 26.

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BASSET, GARDINER C. See RIDDLE, OSCAR.

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REPORT OF THE EXECUTIVE COMMITTEE.

REPORT OF THE EXECUTIVE COMMITTEE.

To the Trustees of the Carnegie Institution of Washington:

GENTLEMEN: Article V, Section 3, of the By-Laws provides that the Executive Committee shall submit, at the annual meeting of the Board of Trustees, a report for publication; and Article VI, Section 3, provides that the Executive Committee shall also submit, at the same time, a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year. In accordance with these provisions, the Executive Committee herewith respectfully submits its report for the year 1915–1916.

During the fiscal year ending October 31, 1916, the Executive Committee held eight meetings. Printed reports of these meetings have been mailed to each Trustee of the Institution.

Upon the adjournment of the Board of Trustees on December 10, 1915, the members of the Executive Committee met and organized by the re-election of Mr. Welch as Chairman for 1916, and by voting that the Assistant Secretary of the Institution act as Secretary of the Committee for the same period.

The President's report gives in detail the results of the work of the Institution for the fiscal year 1915–1916, together with itemized financial statements for the same period and a summary of receipts and expenditures of the Institution to date. The President also submits a report and an outline of suggested appropriations for the year 1917. The Executive Committee hereby approves the report and the recommendations of the President as the report and recommendations of the Committee.

The Board of Trustees at its meeting of December 10, 1915, instructed the Executive Committee to appoint either Messrs. Price, Waterhouse & Co., of New York, or Messrs. Arthur Young & Co., of Chicago, to audit the accounts of the Institution for the fiscal year ending October 31, 1916. Proposals were obtained from these firms, and at its meeting of February 17, 1916, the Executive Committee selected Messrs. Price, Waterhouse & Co. as auditors for the past year. The report of this company is herewith submitted as a part of the report of the Executive Committee.

There is also submitted a balance sheet, showing the condition of the assets and liabilities of the Institution on October 31, 1916, together

with statements of receipts and disbursements since the organization of the Institution on January 28, 1902.

A vacancy in the Board of Trustees, occasioned by the death of Mr. Seth Low, calls for action at the coming meeting of the Board of Trustees. In accordance with further provision of the By-Laws, names to fill such vacancy have been requested and submitted to members of the Board.

William H. Welch, *Chairman.*
Cleveland H. Dodge.
Wm. Barclay Parsons.
Henry S. Pritchett.
Elihu Root.
Charles D. Walcott.
Henry White.
Robert S. Woodward.

November 16, 1916.

Balance sheet, October 31, 1916

ASSETS.

INVESTMENTS:		
Securities (pages 44) . . .	$23,817,320 65	
Cash (uninvested principal) (page 42)	239,635 43	
		$24,056,956 08
PROPERTY ACCOUNT:		
Real estate and equipments, original cost (page 46)	2,470,656 57	
Publications, sale price (page 46)	261,862 75	
		2,732,519 32
CURRENT ASSETS:		
Cash (page 42)	204,947 18	
Stamps and petty cash	300 00	
Income receivable (1916)	124,508 62	
		329,755 80
		27,119,231 20

LIABILITIES

ENDOWMENT	$22,120,000 00	
COLBURN FUND	80,004 64	
RESERVE FUND	1,683,986 55	
INSURANCE FUND	172,964 89	
		$24,056,956.08
INVESTED IN PROPERTY		2,732,519 32
CURRENT LIABILITIES		
Large grants	167,815 30	
Minor grants	44,685 29	
Publication	74,530 34	
Administration	16,061 61	
		303,092 54
UNAPPROPRIATED FUND		26,663 26
		27,119,231.20

Receipts and disbursements for the year ending October 31, 1916.

RECEIPTS.

Interest:		
Endowment—		
Bonds	$1,100,375.00	
Bank balance	6,778.22	
		$1,107,153.22
Reserve Fund—		
Bonds	65,053.75	
Bank balance	2,209.02	
		67,262.77
Insurance Fund—		
Bonds	7,195.47	
Bank balance	141.02	
		7,336.49
Colburn Fund—		
Bonds	1,965.00	
Bank balance	283.90	
		2,248.90
Colburn Fund		51,265.74
Sales of Publications:		
Index Medicus	4,382.19	
Year Book	46.60	
Miscellaneous books	8,115.37	
		12,544.16
Refunds on Grants		1,450 12
Redemption of Securities:		
Cumberland Telephone Co	2,000.00	
Iowa Telephone Co	25,000.00	
Nebraska Telephone Co	13,000.00	
Cleveland Telephone Co	10,000 00	
New York City	50,000.00	
		100,000.00
Miscellaneous:		
Refund, paper, printing	1,591.45	
shipping	227.78	
office	75.75	
sale of copper	43.68	
		1,938.66
		1,351,200.06
Balance October 30, 1915		427,955.38
		1,779,155.44

DISBURSEMENTS.

Investment:		
Securities		$473,702.70
Grants:		
Large	$638,281.41	
Minor	99,401.26	
		737,682.67
Publication		73,733.38
Administration:		
Trustees	3,969.86	
Executive Committee	1,371.32	
Salaries	27,720.00	
Publication—shipping expenses	5,832.67	
Surety, rent, telephone	461.67	
Equipment	341.51	
Stationery	664.79	
Postage, express, etc	404.29	
Printing, paper (including Year Book)	4,272.32	
Office supplies, petty expense	1,545.14	
Building and grounds—		
Supplies, janitor service	1,935.99	
Fuel, light, water	934.52	
		49,454.08
		1,334,572.83
Cash in Banks—		
Endowment Fund	1,796.20	
Reserve Fund	231,863.46	
Insurance Fund	3,636.13	
Colburn Fund	2,339.64	
	239,635.43	
Drawing Accounts	204,947.18	
		444,582.61
		1,779,155.44

Aggregate receipts and disbursements from organization, January 28, 1902, to October 31, 1916.

RECEIPTS.

Interest:		
Endowment bonds	$10,984,189.17	
Reserve Fund bonds	196,445.00	
Insurance Fund bonds	20,140.24	
Colburn Fund bonds	1,965.00	
Income and Building Fund bonds	95,629.06	
Deposits in banks	146,295.83	
		$11,444,664.30
Colburn Fund		52,015.74
Sales of Publications:		
Index Medicus	55,091.88	
Year Book	861.26	
Miscellaneous	60,555.05	
		116,508 19
Refund on Grants		36,716.20
Miscellaneous Refunds:		
Organization	1,825.52	
Office	313.72	
Printing and paper	7,071.45	
Sale of metal cuts	121.08	
Shipping	879.90	
Insurance	4,717.00	
Building	68 53	
Trustees and Executive Committee	57.03	
Bond commission	1,274.37	
		16,328.60
Redemption and Sale of Bonds:		
U. S. Steel Corporation	920,000.00	
Northern Pacific-Great Northern	48,000.00	
Northern Pacific	102,750 00	
Atchison, Topeka and Santa Fe	49,500.00	
Lake Shore and Michigan Southern	47,000.00	
Central Pacific	48,250.00	
Baltimore and Ohio	26,000.00	
Cumberland Telephone Co	2,000.00	
Iowa Telephone Co	25,000.00	
Nebraska Telephone Co	13,000.00	
Cleveland Telephone Co	10,000.00	
New York City	50,000.00	
		1,341,500.00
		13.007.733.03

DISBURSEMENTS.

Investment:		
Securities	$3,042,974.32	
Administration building and site	309,915.69	
		$3,352,890.01
Grants:		
Large	6,491,962.78	
Minor	1,491,004.55	
		7,982,967.33
Publication		581,133.01
Administration:		
Trustees	36,393.98	
Executive Committee	23,884.85	
Honorariums	17,319.81	
Salaries	382,210.03	
Publication—shipping expenses	32,245.41	
Rent, surety, telephone	30,494.47	
Equipment	14,297.07	
Stationery	13,225.92	
Postage, express	20,825.63	
Printing (including Year Book)	39,023.60	
Office expenses	7,039.48	
Building and grounds—		
Supplies, and janitor service	15,447.32	
Fuel, light, water	6,027.45	
Organization (1902)	1,825.52	
Plans and option	5,166.46	
Seal (1903)	555.60	
Miscellaneous	70.23	
		646,052.83
Refund:		
Publication	20.25	
Index Medicus	86.99	
		107.24
		12,563,150.42
Cash in Banks (page 44)		444,582.61
		13,007,733 03

Schedule of securities

Par value.	Securities.	Investment value.	Total.
	ENDOWMENT.		
$21,200,000	U. S. Steel Corporation, registered 50-year 5 per cent gold bonds, Series A, B, C, D, E, and F, due Apr. 1, 1951.	$21,200,000 00	
175,000	Chicago, Milwaukee & Puget Sound Rwy. Co., first mortgage 4 per cent gold bonds, due Jan. 1, 1949.	159,268 00	
13,000	Chicago, Milwaukee & St. Paul Rwy. Co., general mortgage 4½ per cent gold bonds, due May 1, 1989.	12,935 00	
325,000	Lehigh & Lake Erie R. R. Co., first mortgage 4½ per cent 50-year gold bonds, due Mar. 1, 1957.	331,568.30	
237,000	New York City 4½ per cent registered bonds, due Mar. 1, 1963	253,557 50	
150,000	South & North Alabama R. R. Co., consolidated mortgage 5 per cent bonds, due Aug. 1, 1936.	160,875.00	
			$22,118,203.80
	RESERVE FUND.		
50,000	American Telephone & Telegraph Co, collateral trust 4 per cent bonds, due 1929.	45,500 00	
96,000	American Telephone & Telegraph Co., 4½ per cent convertible bonds.	99,456 25	
100,000	Baltimore & Ohio R. R. Co., general and refunding 5 per cent bonds, due 1995.	102,375 00	
50,000	Central Pacific Rwy. Co., first refunding mortgage 4 per cent registered gold bonds, due 1949.	48,250 00	
120,000	Chicago, Burlington & Quincy R. R. Co., general mortgage 4 per cent bonds, due Mar. 1, 1958.	112,805.00	
15,000	Chicago, Milwaukee & St. Paul Rwy. Co., general mortgage 4½ per cent gold bonds, due May 1, 1989.	14,925.00	
155,000	General Electric, 5 per cent gold debenture bonds . ..	158,213 47	
48,000	Great Northern Rwy. Co., first and refunding mortgage 4½ per cent bonds, due 1961.	48,109 25	
100,000	Illinois Central R. R. Co., refunding 4 per cent bonds, due 1955.	89,668 75	
280,000	Interborough Rapid Transit Co, first refunding mortgage 5 per cent bonds, due 1966	276,701 00	
50,000	Lake Shore & Michigan Southern Rwy. Co., registered 25-year 4 per cent gold bonds, due Sept. 1, 1928.	47,000 00	
50,000	Long Island R. R. Co., refunding mortgage 4 per cent bonds, due 1949.	48,285 00	
50,000	New York, Westchester & Boston Rwy. Co., first mortgage 4½ per cent bonds, due 1946.	49,187 50	
50,000	Northern Pacific-Great Northern (Chicago, Burlington & Quincy collateral), joint 4 per cent bonds, due 1921	49,037 50	
50,000	Northern Pacific Rwy. Co., general lien railway and land-grant 3 per cent bonds, due Jan. 1, 2047.	33,101 25	
50,000	Oregon-Washington R. R. & Navigation Co., first and refunding 4 per cent mortgage bonds, due 1961.	46,375 00	
30,000	Pennsylvania R. R. Co., general mortgage 4½ per cent bonds, due June 1, 1965.	29,837 50	
101,000	Pennsylvania R. R. Co., consolidated mortgage 4½ per cent bonds, due Aug. 1, 1960.	105,608 12	
50,000	United Fruit Co., 4-year 5 per cent gold coupon bearer notes, due May 1, 1918.	47,687.50	
			1,452,123.09
23,595,000	Carried forward.......................... ..	....	23,570,326.89

Schedule of securities—continued.

Par value.	Securities.	Investment value.	Total.
$23,595,000	Brought forward...		$23,570,326.89
	COLBURN FUND.		
20,000	Acker, Merrall & Condit Co., debenture 6 per cent bonds.	$13,600 00	
7,000	Buffalo City Gas Co., first mortgage 5 per cent bonds	1,540.00	
8,000	Park & Tilford Co., sinking fund, debenture 6 per cent bonds.	6,400 00	
50,000	Pennsylvania R. R. Co, general mortgage 4½ per cent bonds, due June 1, 1965	51,925 00	
42,000	Pittsburgh, Shawmut & Northern R. R., first mortgage 4 per cent bonds, due Feb. 1, 1952.	4,200.00	77,665.00
	INSURANCE FUND.		
28,000	American Telephone & Telegraph Co, 4½ per cent convertible bonds.	28,978.00	
50,000	Atchison, Topeka & Santa Fe Rwy. Co., general mortgage, 100-year, 4 per cent registered gold bonds, due 1995.	50,056 25	
25,000	Bell Telephone Co. of Canada, debenture 5 per cent bonds, due Apr. 1, 1925.	24,760 00	
30,000	Chicago, Burlington & Quincy R. R. Co., general mortgage 4 per cent bonds, due Mar. 1, 1958.	28,237 50	
1,000	Chicago, Milwaukee & St. Paul Rwy. Co., general mortgage 4½ per cent gold bonds, due May 1, 1989.	995.00	
6,000	Great Northern Rwy, first and refunding 4¼ per cent bonds, due 1961.	5,979 50	
6,000	Illinois Central R. R. Co., refunding mortgage 4 per cent bonds, due Nov. 1, 1955.	5,227 50	
24,000	Pennsylvania R. R Co, consolidated mortgage 4½ per cent bonds, due Aug. 1, 1960.	25,095.01	169,328.76
23,892,000			23,817,320.65

NOTE.—Following this table, the report of the Executive Committee contained the table of Real Estate, Equipments, and Publications, which also appears on page 22 of the report of the President of the Institution. It is omitted at this point to avoid the repetition. See page 22.

Balances due minor grants.

Astronomy:	
Kapteyn, J. C	$333.40
Archeology:	
Van Deman, E. B	1,400.00
Morley, S. G	408.79
Bibliography:	
Index Medicus	10,721.09
Biology:	
Department of Experimental Evolution	300.00
Dutra, J	100.00
Jackson, R. T	282.50
Morgan, T. H	1,925.05
Vaughan, T. W	362.80
Do	16.70
Do	300.00
Botany:	
Britton and Rose	1,165.00
Chemistry:	
Jones, H. C	1,252.80
Morse, H. N	666.70
Noyes, A. A	300.00
Osborne, T. B., and L. B. Mendel	4,983.43
Richards, T. W	450.00
Sherman, H. C	180.00
Remsen, Ira	916.67
Geology:	
Chamberlin, T. C	648.08
Moulton, F. R	425.00
History:	
Osgood, H. L	200.00
Turner, Frederic J	3,600.00
Literature:	
Bergen, Henry	300.00
Mathematics:	
Morley, Frank	600.00
Meteorology:	
Bjerknes V	450.00
Paleontology:	
Case, E. C	250.00
Hay, O. P	943.70
Wieland, G. R	592.50
Philology:	
Churchill, William	2,083.38
Physics:	
Nichols, E. L	2,500.00
Nipher, F. E	255.80
Physiology:	
Reichert, E. T	1,500.00
Zoology:	
Castle, W. E	416.70
Unallotted:	
Minor grants	3,855.20
	44,685.29

Balances due large grants.

Department of Botanical Research	$4,855.00
Department of Economics and Sociology	25,724.62
Department of Embryology	17,425.84
Department of Experimental Evolution	7,151.16
Geophysical Laboratory	23,197.88
Department of Historical Research	4,995.00
Department of Marine Biology	1,000.00
Department of Meridian Astrometry	4,807.18
Nutrition Laboratory	14,130.27
Division of Publications	2,864.43
Solar Observatory	38,135.50
Department of Terrestrial Magnetism	23,528.42
	167,815.30

Balances due publication account.

American Ethnological Society	$900.00
Barnard, E. E	2,060.00
Barus, Carl	1,138.00
Boss, Benjamin, *et al*	2,000.00
Carnegie Institution of Washington	51.58
Churchill, William	1,348.69
Clark, H. L	7,859.67
Concordance to Keats	4,500.00
Contributions to Embryology	1,823.00
Do	3,754.10
Crampton, Henry E	7,652.15
Golder, Frank A	900.00
Goodale, H. D	322.66
Hedrick, H. B	1,359.80
Hill, R. R	2,600.00
Index to State Documents	7,882.61
Index to U. S. Documents relating to Foreign Affairs	8,397.93
Ivens, W. G	1,600.00
Knobel, E. B	1,300.00
Meyer, B. H	3,000.00
Morley, S. G	2,094.32
Moulton, F. R	2,463.25
Papers from Department of Marine Biology, Pub. 213	2,039.69
Reprint of "The Old Yellow Book"	425.03
Republication of Classics of International Law	6,036.56
Researches, Department of Terrestrial Magnetism	3,943.30
Weed, L. H	1,754.80
Unallotted	15,256.77
	94,463.91
Paper in stock, to be used in publications	19,933.57
	74,530.34

REPORT OF AUDITORS.

NEW YORK, *November 28, 1916.*

To the Executive Committee, Carnegie Institution of Washington:

DEAR SIRS: We beg to report that we have audited the accounts of the Institution for the year ended October 31, 1916.

The securities representing the investments have been exhibited to us and we have ascertained that the income therefrom has been duly accounted for. We counted the cash on hand and verified the cash in bank with certificates from the depositaries.

Properly approved vouchers and cancelled checks have been exhibited to us for all payments made during the period by the administrative office at Washington, but we did not audit the books of the various departments, as these departments are audited by the Bursar under authority of your Committee.

We checked the appropriations and allotments with certified copies of the minutes of the Trustees and of the Executive Committee.

In accordance with the established practice of the Institution, real estate and equipment are carried at cost, and all publications on hand at their selling value, and both the unexpended appropriations and the balance of income receivable for the calendar year are taken up in the balance sheet of October 31, 1916. Securities owned are carried at original valuation or cost, the aggregate of which is less than the market value.

Subject to the foregoing explanation, we certify that the statements printed on pages 41 to 47 of the Year Book for 1916 are in accord with the books of the Institution and are correct.

We found the books to be accurately and carefully kept and every facility was afforded us during the course of our audit.

Yours very truly.

PRICE, WATERHOUSE & CO.

REPORTS ON INVESTIGATIONS AND PROJECTS.

The following reports and abstracts of reports show the progress of investigations carried on during the year, including not only those authorized for 1916, but others on which work has been continued from prior years. Reports of Directors of Departments are given first, followed by reports of recipients of grants for other investigations, the latter arranged according to subjects.

DEPARTMENT OF BOTANICAL RESEARCH.*

D. T. MacDougal, Director.

Most of the problems under consideration are mentioned in the following paragraphs, which also indicate methods of procedure, describe progress, and summarize the more important results.

The study of the available facts and accepted conclusions concerning photosynthesis, perhaps the most important single process in the organic world, eliminates the theory of Baeyer from the possible explanations. The experimental research on this subject is planned on the conception that its initial stage is much more complex than a simple condensation of formaldehyde to sugar.

The cacti have been selected for the study of the carbohydrate economy of plants, and no evidence has so far been uncovered indicative of special formative substances. These and other plants may get into a state of starvation for sugar, although having an ample supply of starch on hand which can not be hydrolyzed at temperatures inhibiting enzymatic action or when the shoot is in a desiccated condition.

The lower limit at which certain cacti may begin to grow has been found to vary from 10° to 25° C. in the same plant, and the upper limit at which growth ceases from 26° to 43° C. in a single plant. Temperature coefficients of 2 or more for every rise of 10° C. were found between 10° and 30° or 35° C. Maxima of 49° C. for growth were encountered. Endurance of temperatures of 52° and 53° C. were noted. All temperatures were those of the plant-body instead of the air, as ordinarily taken.

The precision auxograph has now been perfected to a point where it will record a change of 0.0004 inch in length or thickness. It has been made in a form suitable for recording growth or shrinkage of plants, imbibition swellings, or the swelling of colloids of interest in connection with growth.

Eriogonum nudum exhibits a course of growth in which the maximum is in daylight, and the rate is largely determined by the balance between absorption and water-loss, no recognizable inhibiting effect by light being found.

The screens of special glass have now been developed to a point where they can be manufactured in 16 cm. squares in quantity.

Imbibition is defined as the distensive force in the earlier stage of growth of the cell, and it plays an important but diminishing part as vacuoles are formed and the protoplast enlarges. Osmosis increases in importance with the development of the cell. Most plant-cells have a greater capacity for water when slightly alkaline, unlike gelatine, which swells most in acidified solutions. In consequence of this fact acidity checks or retards growth.

*Situated at Tucson, Arizona.

The capacity of shoots of cacti for water increases up to maturity at an age of a year or more, with the dry weight, then decreases. Disks cut from the joints of young platyopuntias increase in thickness about 23 per cent in water and in alkali, but only 16.4 per cent in acid, while samples from plants a year old swelled 40 per cent in water, 52 per cent in alkali, and 36.6 per cent in acid.

A search for a mixture of colloids that would exhibit imbibition similar to those of the plant disclosed that gelatine with a smaller quantity of agar makes such a mass. Gelatine swells most in acid, and agar in distilled water. The mixture shows greatest swelling in alkali, and simulates the plant as to general composition and behavior.

The rate of transpiration, movements, etc., is influenced by the capacity of the plant for imbibition. The water-holding capacity of tissues of cacti is less at night than in the daytime, although the stomata are open at night and closed during the day.

The relative parts which might be played by imbibition and turgor in the growth of pollen-tubes in cane sugar and acids and alkalies were studied. The colloids in these cells are of a kind which swells more in acid than in alkali in very low concentrations.

The ratio of precipitation to evaporation is found to be the factor which limits the areas of forest, grasslands, and desert, and a new subdivision of the vegetational areas of the United States has been worked out, and with this a new method of determination of the domination of different growth-forms has been devised and put into use.

Flattened bodies of plants like those of the platyopuntias in a meridional position receive more heat in the course of a day at Tucson than those in an east-and-west position, and attain temperatures of 53° C. (124° F.) or more. Transpiration, dry weight, etc., correspond to the exposure.

The roots of different plants show varied relations to oxygen, which is correlated with soil-penetration and habit. Similar differences as to temperature at which growth proceeds have been measured. The forms taken by root-systems of plants may be greatly affected by change in environmental conditions.

The roots of the swamp willow (*Salix* sp.) grow for extended periods in atmospheres devoid of oxygen.

For study in connection with the physical characters of their habitats, 300 determinations have been made of the concentration of the saps of plants in mountain and desert habitats. The sap of parasites is generally of a higher concentration than that of the host, though not always or necessarily so, as suggested by MacDougal in 1910.

A map of the vegetational areas of the United States, based on behavior and anatomy of growth-forms, has been brought to the publication stage.

Beetles (Leptinotarsæ) introduced at Tucson show gradual morphological changes which do not seem to be reversible, and which react as

Mendelian recessives when crossed back with the original stock. Some physiological changes react as dominants in crosses. Some of the 20 mutants previously observed have recurred. Accumulating evidence tends to show that the mutability is not a hybridization splitting.

Wide divergences were found in the progenies of single species of *Oenothera* from widely separated localities and some striking aberrants or mutants were found.

The taxonomic investigation of the Cactaceæ has been carried to a point where it has been possible to prepare the first of the volumes dealing with the Pereskieæ and Opuntiæ, in which it is proposed to give a comprehensive treatment of the family.

Some extensive regions in South America inhabited by cacti remaining unexplored, Dr. N. L. Britton, one of the associates engaged in the research, has undertaken the expense and execution of the field-work.

The Salton Sea has come down to a stage where the level is oscillating, with a final reduction of 40 inches in depth annually. The total solid matter in solution amounted to 1.6 per cent on June 10, 1916. The increased salinity has been followed by a modification of the activities of organisms supposedly active in the precipitation of calcium, but that element is still being shown in a proportion not consistent with mechanical concentration.

The revegetation of an island has been followed from a stage in which it was inhabited by but two individuals in 1908 to 1916, when the census showed 470 individuals, representing 10 species.

Variations in climate affecting vegetation in the preceding geological periods are attributed chiefly to the frequency and distribution of cyclonic storms. Solar and terrestrial data for each day of seven years have been computed in this connection.

The study of the Mohave River, the chief streamway of the Mohave Desert, leads to the conclusion that this river has been of the truncated type during the greater part of its history, and that its waters cut across the barrier and flowed into Death Valley for a very brief period only. This evidence is of great value in making out the evolutionary history of the vegetation of this ancient desert.

Precipitation being limited in desert regions, the underflow becomes of the greatest importance to vegetation. It is shown that artesian conditions do not require a bowl-shaped basin, but that buried streamways in trough-like valleys may have layers of impervious clays and of sand and gravel in which water collects under such head that it may rise to the surface or above it when tapped. Some generalizations of practical value in putting down deep wells are reached.

Wind erosion in the Painted Desert and the torrential flow of a desert river when its channels have been progressively cleared are included in the surface phenomena of arid regions which are being kept under systematic observation.

PHOTOSYNTHESIS, IMBIBITION, AND GROWTH.

Studies in Photosynthesis, by H. A. Spoehr.

The Baeyer theory of photosynthesis which for almost half a century has dominated investigation in this field is being made the subject of critical experimental study. The basis of this theory is the condensation of formaldehyde in aqueous solution by means of alkalies, as discovered by Buterlow in 1861. No consideration has ever been given to the question whether this reaction actually takes place under conditions such as exist in the chlorophyllous leaf. Accordingly a series of tests was undertaken to determine whether formose is formed from formaldehyde in weak alkaline or in neutral solution and at ordinary temperatures, and whether the reaction is influenced by sunlight. Pure 3 per cent solutions of formaldehyde (free from methyl alcohol and formic acid) were used, with the salts in N/10 concentration, in glass flasks. These were exposed directly to the sunlight for 5 months, and the amount of sugar formed determined every month. Not a trace of sugar was formed by $CaCO_3$, $3MgCO_3.Mg(OH)_2.3H_2O$., K_2CO_3, $KHCO_3$, KOH, colloidal Fe $(OH)_3$, in the dark or the sunlight. $ZnCO_3$ formed a trace in the light, but none in the dark. Light does increase the sugar formation with the stronger alkali hydroxides. Pure neutral formaldehyde solutions in glass and quartz vessels formed no sugar at all in the sunlight. Even then, if formaldehyde were formed as the first reduction product of carbon dioxide, which has previously been shown to be highly improbable, it would seem that this second step in the photosynthetic process must proceed in a different manner than is supposed by this theory. The whole process is, no doubt, of a nature much more highly complex, involving the operation of unknown enzymes in cooperation with the chloroplasts.

The Carbohydrate Economy of Cacti, by H. A. Spoehr.

The phenomenon of metabolism presents such a complex and multiplicity of molecular disintegrations and reconstructions that a comparative study of plants of different physiological behavior is of the greatest importance in order to gain a clear and comprehensive conception of this activity. The higher plants exhibit differences not so much as to the course and nature of their metabolism, but rather as to the accumulation of substances formed either as by-products or as intermediate steps in the complete katabolism. These differences are often the result of structural or environic conditions. For the purpose of studying these relations the cacti offer very interesting material, both on account of their structural peculiarities and the rather extreme climatic conditions under which they live. Certain of the characteristics of the metabolism of these plants have already been thoroughly studied by Dr. H. M. Richards. However, our knowledge

of the essential features of the earlier stages of the metabolic activity of cacti is still very incomplete. In studying the various vital processes of these plants, it is possible to deal with the visible products, and these products afford certain proof of and insight into the metabolic activity, although the exact nature and causes of these changes may be still undetermined.

The carbohydrates predominate in the general food economy of the cacti. It was necessary to develop accurate methods to determine various groups of sugars of different physiological significance. *Opuntia blakeana* and *O. discata* have been most generally used, and analyses, together with determinations of the rate of respiration, have been carried out under a variety of experimental and natural conditions. A growing young joint seems to affect the food-supply of the mother joint but very slightly, apparently becoming autonomous in this respect very early in its development. The rate of respiration, as well as of photosynthesis, is naturally much higher in the growing than in the mature joint. There is no evidence of the existence of special formative and respiratory substances, and in regard to food-content young and mature joints exhibit the same or parallel reactions to changes in environic conditions, *e. g.*, temperature or water-supply. The nature of food consumption is shown in a series of starvation experiments; these, when compared with the results from normal material, indicate that although ordinarily the metabolic functions make submaximal demands on the food-supply, during times of intense heat and drought the plant is in a state of privation in regard to certain sugars. It remains to be determined whether this labile equilibrium of starch $\rightleftarrows$ monosaccharide is purely a temperature effect or is here related also to the water-content of the plant.

The function of the slimes, which are of pentosan nature, is still quite obscure. It is certain, however, that the pentoses are not to be regarded as inert components, but are drawn into the complex of metabolic activity quite as actively as the hexoses. In this work very helpful assistance has been rendered by Mr. J. M. McGee.

Temperature and Growth, by D. T. MacDougal.

The lower limit at which growth may begin, the degree at which it proceeds most rapidly and continuously with regard to the stage of development of the organ measured, the point at which a higher rate may be maintained for a short period, and the upper limit of temperature have been the subject of many observations. Some attention has also been paid to the acceleration ensuing from definite rise in temperature with reference to the van't Hof law of chemical action.

Growth includes a number of separate processes, each of which goes on at a rate modified by the temperature by the amount of material

brought into the chemical reactions and by the concentration of the products of the reactions. The rate and amount of expansion of a growing organ depends upon osmosis and imbibition, which are modified in a manner not closely conformable to the van't Hof law. A statement of definite temperatures for any of the critical points will lack final value unless given as the resultant of a formula expressive of the intensity of the contributory factors. Attention has been paid to the upper and lower limiting temperatures of growth. It might be possible in either case to find some theoretical point where one of the processes would be stopped absolutely with all of the other contributory factors at an optimal intensity. It does not follow, however, that growth will begin when a rising temperature passes the lower limit, or that it will carry on to the upper limit.

Extensive tests and measurements of about 40 growing shoots of *Opuntia* in their native habitats showed that the temperature of the body at which enlargement might begin ranged from 10° to 25° C. Growth ceased under varying conditions at temperatures ranging from 26° to 43° C.

The rates of growth of an etiolated shoot of *Opuntia* during a month in a dark room is illustrated by the following excerpts from the notes:

Varying rates of 1.2, 1.2, 1.15, 0.85, and 1.15 daily at 16 to 18° C.
Increasing rate of 2.9, 3, 3, 3, 3.2, and 3.44 mm. daily at 26° C.
Increased rate of 3.6, 6.7, and 9.6 mm. daily at 30° C.
Increased rates of 11.4, 11.4, 8.4, 9.2, and 11.4 mm. daily at 31.5° to 32° C.
Decreased rate of 5.3 to 5.7 mm. daily at 18° to 19° C.
Increasing rate of 8.4 to 16.8 mm. daily at 39° C.
Decreasing rate of 5.4 to 9 mm. at 39° to 40° C.
Increased rate of 13.2 mm. at 35° C.
Increased rates of 16.8 to 19.2 mm. daily at steady temperature of 38° C.
Decreased rate of 13.2 mm. daily while temperature rose from 38° to 45° C.
Cessation of growth at 45° C.
Resumption of growth at 46° C.
Increased rate of 25 mm. daily during the first hour at 46° C.
Decreased rate of 20 mm. daily for 4 hours at 46° C.
Increased rate of 20.4 mm. daily during an hour at 45° C.
Decreased rate of 18.5 mm. daily during hour temperature was raised to 48.5° C.
Cessation of growth at 48.5° C.
Resumption of growth at rate of 19.2 mm. daily at temperatures of 48° and 46° C.
Growth of 15 mm. daily as temperature rose to 47.5° C.
Cessation of growth at 49° C. with air-temperature 40° C.
Resumption of growth after 20 minutes at 49° C., but soon stopped.
Temperature of plant 52° C. for half an hour; air 43° C.
Resumption of growth at 49° C. with air at 41° C. at rate of 9.6 mm. daily.
Similar results with many plants at high temperatures were obtained.

The above records show a gradual progression of the rate as the development of the shoot proceeded. The comparison of the rate at any point, as for example, at 16° to 18° C., is made with the next observed rate at 25° or 26° C. to obtain the temperature coefficient. The advanced stage of development when the temperature again

returns to 16° to 18° C. would be responsible for a rate higher than the preceding one at that temperature. The average rate at 16° to 18° C. was first found to be 1.5 mm. daily and that at 26° C. was 3.1 mm. daily, giving a coefficient of 2 for the rise of 10° C. Inspection of other results gave higher values. A point is reached below 35° C. where a maximum rate is obtained which is not maintained. When a plant is placed under constant exposure to any temperature in their range, a decreasing high rate is exhibited. When this has run its course, a new rise in temperature is followed by a new maximum, from which the plant slows down. This stepping up and sliding back appears to prevail practically to the upper limit of growth.

The observations reach the high limit of 49° C. for the growth of the higher plants. A new limit of endurance of 52° C. for growing plants was also observed. Growth after such exposure was resumed at the high limit of 49° C. as before.

The discovery of these upper limits of endurance and growth of developing organs are probably conditioned on the use of new methods of taking temperature rather than upon any specialization of the protoplasm of the cacti. It has been assumed that the temperature of growing organs approximated that of the air in nearly all studies which have hitherto been made on this subject. A. M. Smith secured body temperatures of the giant bamboo (*Dendrocalamus giganteus*) as much as 6° C. above that of the air in his work on the growth of that plant in Ceylon in 1906, and the use of such temperatures made possible some advanced generalizations. The differences between the temperature of the air and of the growing shoots of cacti are as much as 8° or 9° C. at times. Thermometers of the "clinical" type with thin bulbs were used. The thin bulbs were fixed in the tissues of joints from which new shoots were arising, and in growing shoots similar to those being measured.

A Precision Auxograph, by D. T. MacDougal.

The changes in volume of growing organs and the measurement of the swelling of colloids similar to those concerned in the process have made necessary the designing of recording apparatus applicable to both kinds of material. The essential part of such an apparatus consists of a delicately balanced compound lever, carrying a tracing-pen on one free end and having an arrangement by which the movement to be measured may be applied at various intervals on the other free arm. Magnifications of 10 to 50 are secured in this manner. A clock-driven cylinder of the standard used in thermographs, barographs, etc., carries the recording sheet, which has been specially designed. The ruled space on these sheets is 8 cm., divided into millimeters, numbered on the "fives" and shaded on the "tens." The paper is of a quality

to take a tracing from a fine pen-point, making it possible to divide the millimeters and to read actual changes in size of 0.01 mm. or 0.0004 inch. The lever set is supported on a rack-and-pinion column with a vertical movement of 10 cm. and the clock may be adjusted at any height on a fixed vertical column by a sleeved arm and set-screw. A dozen of these instruments have been constructed and used in getting the accompanying results on growth.

Growth of Eriogonum in relation to Light, Temperature, and Transpiration, by Francis E. Lloyd.

It was mentioned in a previous report (Carnegie Institution Year Book for 1912, p. 61), that in *Eriogonum nudum* the transpiration-rates and growth stand in reverse relation to each other, the magnitudes of water-loss being sufficient to produce a checking of growth or even shrinkage of volume of the growing parts. It was inferred that this checking of growth was the direct result of net water-loss, and not of supposed inhibiting effect of light upon growth, a doctrine which has been passively accepted for many years. During the present season opportunity has presented itself for a more careful study of the behavior of the plant in question, which, on account of its long, slender, naked internodes, supplies a peculiarly good object for investigation. This was carried on by methods of field auxanometry, the apparatus being so arranged that the growing portion under observation could be inclosed within a chamber in such manner that humidity, both quality and quantity of light, and, to a large extent, temperature also, could be controlled.

The average rates of growth during the daylight periods were found to be usually greater and only occasionally less than in the periods of darkness, depending upon the state of the growing part, temperature, humidity, or the amount of water available for that part.

The daily march of growth is as follows: During the early daylight hours until about 8 there is usually a slight rise in growth-rate. After that hour the rate falls to a low value, or, much more frequently, there ensues an actual shrinkage. This is the period during which the loss of water by transpiration is rapidly increasing, reaching its maximum at about noon. Coincidentally with the checking of transpiration, the growth-rates rapidly increase in value, the maximum rate being attained by 1 or 2 p. m., and thereafter maintained, with fluctuations, until 6 p. m., when the rates fall to the night values. The afternoon rates are great enough to more than make up for the negative behavior of the morning, except, as above stated, under unusual conditions.

That light can not be held to account for the retardation of growth during the morning hours as above indicated has been shown to be an untenable view, since it was found possible experimentally to alter the rates both positively and negatively quite independently of the

constancy, increase, or decrease of illumination, even when this has been increased with respect to the growing part by insolation from three directions. There seems, indeed, to be no maximum insolation normally occurring in the field at this locality which can cause any cessation or inhibition of growth when conditions obtain which insure water-supply to the growing part. Thus, when a cessation of growth is apparent, it may be checked, and high rates instituted, by the removal of leaves (which divert the water-supply), by increasing the vapor-tension in the vicinity of the growing part, or by merely increasing the temperature when the volume of the growing part is small (as when the internode under observation is young). These positive changes may occur coincidentally with increase of illumination from the blue or red portions of the spectrum to full insolation.

It thus appears that the dominant factor in the mechanism of growth is the water-balance of the growing part, a conclusion in accord with studies of A. M. Smith, Lock, W. L. Balls, and Blaauw, thus substantiating (contrary to the widely diffused belief) the view earlier pronounced by MacDougal that light under normal conditions does not inhibit growth.

Glass Screens for testing the Influence of Light upon Growth and Development, by D. T. MacDougal.

Glasses for the purpose of screening organisms from various parts of the solar spectrum have been fixed upon by cooperation with Dr. H. P. Gage, of the Corning Glass Works. The manufacture of this material was at first confined to the molding of bell-jars. Not all of the desired ones could be treated in this manner, and during the present year the effort was made to blow cylinders which could be flattened and annealed into sheets. This process has also proved unsatisfactory and has been discontinued. The method finally fixed upon is that of stamping out small sheets 6.5 by 6.5 inches (about 16 cm. square). Some glasses in this form have already been secured and others are in course of manufacture.

The Distensive Forces in Growth, by D. T. MacDougal.

The embryonic cells of the growing regions of plants, to the activities of which the external measurable features of growth are due, are compressed globular masses of colloids of varying composition and dispersion, including both nitrogenous gels and mucilaginous material of the pentosans and hexoses. The outermost layer of each protoplast is the seat of specialized activities and is of greater density than the remainder of the unit. Not all solutes or suspensions pass through it with equal facility. The kinetic theory of osmosis, by which a pressure is set up inside this membrane by the impact of the molecules

which can not pass through it, will be adequate for the purpose of the present discussion without reference to its inadequacies in some respects.

The greater part of the mass of the protoplast is at first a fairly homogeneous mass mechanically, with the exception of the large nucleus. No distinct "cavities" or large hiatuses in the gelatinous matter are to be seen. The only forces which might cause the cell to enlarge in this condition would be the swelling of imbibition and the osmotic action of the colloids. Definite information on this latter action in the plant-cell is not available, but it is safe to assume that the molecular aggregates of the colloids would act much in the same manner as single molecules or smaller associations of them.

The presence of hexoses and various salts soon results in the accumulation of water in places in the mass and these irregular vacuoles become the seat of a much greater osmotic pressure than that displayed by the colloids. The protoplast soon attains a stage in which it presents the mechanical features of a sac of denser material with irregular lighter strands and sheets of cytoplasmic gel separating clearer spaces or vacuoles, the nucleus somewhat diminished in size and variously held in the lighter cytoplasm. The cavities or vacuoles undoubtedly contain colloidal material which in its high state of dispersion carries its capacity for swelling with hydration.

The picture of the cell as thus described includes the principal features by which it and thousands of its fellows expand and thus give rise to the enlargements measurable as growth and to the shrinkages or diminution of volume which have hitherto received but little attention. The state of distension or turgidity of the cell has been chiefly attributed to osmotic pressure and it has been customary to assume that the expansive force of growth was practically identical with its action. The use of isotonic solutions in the measurement of turgor is based on this assumption, and the acceptance of the freezing-point of the sap as a measure of the pressure of the cell rests on the same conception.

It is clear, however, that imbibition or hydration of the colloids in addition to their osmotic pressure is also a force to be reckoned in such determinations. Interpretations of the action of external agencies, such as temperature on growth, must take into account not only the effect exerted upon respiration, enzymatic action, and other reductions and oxidations, but also the effect of concentration and the state of the membrane in osmosis. In addition, the colloids (including those of the cell-wall, the lining layer, the cytoplasmic sheets, and the nucleus) are undergoing changes in mass as well as in imbibition or hydration capacity. The hydration phenomena are not those of a single gel, nor is the resultant a mechanical one, for the admixture of two or more colloids produces a substance which, as seen in the case of

gelatine and agar, may swell in a manner not to be predicted, in the present state of theories as to the structure of colloids.

A varying amount of water is lost at all times by transpiration from the growing parts of plants and may exceed the supply to such an extent that a stoppage of growth or an actual shortening may ensue; how far this is accompanied by a slackening or cessation of adsorption of new material in protoplastic colloids can not be said at present. Marked variations in volume of the plant, however, are caused by such excessive water-loss.

The expansion or enlargement feature of growth is therefore a complex process, the principal energy for which comes from imbibition and osmotic pressure of colloids in the earlier stages of the cell. Osmosis plays a larger part in the later stages of distension. The tissues and embryonic regions of the plants tested in the experimental work at the Desert Laboratory swell more in weak alkaline solutions than in acid or neutral solutions. Studies of the daily course of growth show that it is most rapid at the time when the acidity of the sap is at a minimum or when a neutral or alkaline condition has been reached. High acidity with decrease of imbibition and excessive water-loss may check or stop growth with consequent shortening of growing organs.

The Effect of Age, Acids, and Alkalies upon Imbibition by Growing Regions and Tissues of Plants, by D. T. MacDougal.

The capacity of a developing organ for taking up water by osmosis and imbibition is a feature which plays a very important part in growth. Mature organs generally have a greater capacity than those in an embryonic condition. The possibility of making measurements of material at various ages and under different conditions was one of the important advantages of using the cacti in studies on growth.

Clean disks 12 mm. across were cut from the flattened joints of *Opuntia.* Three of these were arranged in a triangle in the bottom of a Stender dish and a triangle of thin sheet-glass arranged to rest its apices on the three disks. The vertical swinging arm of an auxograph was now adjusted to a shallow socket in the center of the glass triangle, while the pen was set at zero on the recording sheet. Water or a solution being poured into the dish, the course of the swelling was traced on a sheet ruled to millimeters.

That the amount of imbibition depended on the presence of certain recognizable substances, not on the mechanism of the living cell, was demonstrated by the fact that dried disks gave proportionate differences equivalent to those of living material.

The average thickness of disks varied from 4 or 5 mm. in the case of young joints to 18 or 20 mm. in mature ones. The apical parts of joints showed greater capacity for absorption than the basal ones in

the proportion of 21 or 22 to 16 or 17 per cent. Comparative tests were finally based on disks taken from apical regions. The capacity for absorbing water was seen to increase up to maturity (about 1 year old) then to decrease, as illustrated by the following set of tests with *Opuntia blakeana*, made May 17 to 29, 1916:

	Young.	Mature.	Old
	p. ct.	*p. ct.*	*p. ct.*
Swelling (distilled water)	24 3	50	41.3
Dry weight	16 03	24	25 95
Total sugar	44 91	38 04	35.27
Fiber	4.65	9.13	11.51

The amount of imbibition is seen to be not a continuous function of any one substance or group of substances. This would harmonize with the results of swelling mixtures of gelatine and agar described in the next paragraph.

The phenomena of proportionate swelling of gelatine in water, acids, alkalies, and salt solutions have been mistakenly used hitherto in attempts at explanation of the mechanism of growth. It has been demonstrated by repeated tests that the tracts of the growing cells studied as well as maturing or mature tissues do not swell more in acid than in distilled water or alkali, as will be illustrated by the following results:

Swelling of disks of Opuntia.

	Distilled water.	Sodium hydrate N/100	Hydrochloric acid N/100.
	p. ct	*p. ct.*	*p. ct.*
Young	23 6	22 9	16 4
Mature	40	52 1	36 6

It is conclusively established that both young and old tissues take up more water when neutral or alkaline. Acidity, therefore, in addition to retarding enzymatic action and respiration, indubitably operates to retard growth by its effects on imbibition by plant tissues.

The Swelling of Colloidal Mixture in Water, Acids, and Alkalies, by D. T. MacDougal.

It being demonstrated that growing masses of embryonic cells in plants and tracts of mature tissue do not show their greatest capacity for the imbibition of water in acidified but in alkaline solutions, it was sought to find what substance or mixture of substances would behave in a similar manner. The first inquiry was made with agar,

which is a pentose presumably having some qualities identical with those of the mucilages of the plant. Dried cylinders and sheets of this material were first subjected to the tests, being placed under the auxograph after the manner in which disks of living material were treated, as described in a previous paragraph. The results compared with the swelling of gelatine were as follows:

	Sodium hydrate N/100.	Hydrochloric acid N/100.	Water.
	p. ct	p. ct.	p. ct.
Swelling of agar	124 4	113	197
Swelling of gelatine	250	382	83

As the plant did not show water-relations which might be interpreted as a mechanical resultant of the separate action of gelatine or agar, it was next proposed to test the reactions of a mixture in which these substances would be blended. The first test-mass was one which consisted of about 3 parts of agar and 2 parts of gelatine; both were soaked and melted separately; then the gelatine was poured into the hot agar, which was kept near the boiling-point of water for a half hour. The mass was then poured onto a glass slab for cooling. Two days later it was stripped off as a fairly clear and transparent sheet slightly clouded, the average thickness of which was 0.2 mm. Strips about 5 by 7 mm. were placed under the apices of sheet-glass triangles in glass dishes after the manner in which plant sections had been tested, and auxographs were arranged to record the action of acids, alkalies, and distilled water.

The first trial, made on July 21, gave the following final relative thickness of the strips as compared with the original: Distilled water 850 per cent; nitric acid (N/100) 725 per cent; hydrochloric acid (N/100) 750 per cent; sodium hydrate (N/100) 950 per cent. These results were obtained while some enlargement was still in progress, but which would not in the end disturb the relations given. A second test on the following day at temperatures of 61° to 65° F. gave the following: Distilled water 675 per cent; hydrochloric acid 625 per cent; nitric acid 687.5 per cent; sodium hydrate 750 per cent. These results were taken to be of such importance that a series of mixtures of agar with 20, 50, and 80 per cent of gelatine by dry weight were made up. The mixtures were poured into molds on glass plates and dried sheets from 0.1 mm. to 0.6 mm. thick were obtained. The first series of measurements given below includes the results of tests under varied conditions not only of thickness of the samples, but also of temperature, length of period of swelling, tension of instruments, etc. Each set of three measurements of the swelling in the three liquids is therefore to be considered separately.

The outstanding fact that a mixture consisting mostly of gelatine to which a small proportion of agar has been added shows its greatest swelling in alkaline solutions is the most important feature of these results. The mixture in question is available as a physical analogue which has already been found useful in the study of growth and swelling of plants. Mixtures consisting half or more of gelatine give acid swellings of second rank and expand least in water. Mixtures containing more than half of agar swell most in water, with the effects of weak acids and alkalies fairly equivalent.

Swelling of agar-gelatine mixtures.

Gelatine 80, agar 20 parts.			Gelatine 50, agar 50 parts			Gelatine 20, agar 80 parts.		
Sodium hydrate N/100	Hydrochloric acid N/100	Distilled water.	Sodium hydrate N/100	Hydrochloric acid N/100	Distilled water.	Sodium hydrate N/100	Hydrochloric acid N/100	Distilled water.
p. ct.	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*	*p. ct.*
800	700	425	788	788	692	600	400	1,150
875	775		500	333	1,133	600	600	1,450
600	900		600	350	525	600	700	1,200
850	650	558	675	225				
600	600	275						

The results described constitute a gratifying success in the search for a colloidal mixture which would exhibit the swelling reactions of plant-cells. The variations in imbibition exhibited by these mixtures are of a kind and range displayed by the plant, and it seems probable that the addition of a hexose albumen and of minute quantities of salts would make a still more accurate analogue of the plant. Both agar and gelatine are colloids of the emulsoid type believed to be composed of two aqueous phases differing from each other only in the relative concentration of the organic compound in the water. The behavior of agar-gelatine mixtures is therefore of much interest in connection with prevalent theories of the structure of gels of this type, as well as with relation to the nature and behavior of the plant colloids.

Causes of Variations in the Transpiring Power of Cacti, by Edith B. Shreve.

During the assembly of the data secured from the investigation of the transpiration of cacti, which has been under way for the past two years, it became evident that further experimentation was advisable. Measurements of transpiration, of water-intake by the roots, of water-absorbing capacity of the tissues, of relative acidity of the tissues, and of stomatal movement have now been made under various controlled environmental conditions. These experiments have shown the existence of a constant interrelation between transpiring power and water-holding capacity of tissues, water-content of the aerial parts of the

plant, and also degree of openness of the stomata. Likewise there appeared an interrelation between the water-intake by the roots and the water-holding capacity of the tissues and also the water-content of the plant. The following conclusions may now be drawn:

(1) The transpiring power is greatly influenced by light intensity, air-temperature, water-content of tissues, and available soil moisture; these factors clearly exert their influence indirectly through their action upon some internal process.

(2) Variations in the rate of water-intake by the roots exist and are evidently independent of variations in transpiration. Variations in water-intake at the roots are due, on the one hand, to variations in soil-retentivity, and on the other to variations within the plant itself. The latter may be further subdivided into variations in absolute transpiration-rate and in water-absorbing power of the tissues. The variations in soil retentivity may be reduced to zero, for experimental purposes, by the use of water-cultures or supersaturated soil, and then the absolute water-intake divided by the absolute transpiration for the same period gives quantities whose variations may be traced neither to soil retentivity nor to transpiration changes. This quantity, A/T, is given the name "secondary absorbing power." It was found to vary in a direction which is always opposite to the variations in T/E for the same period, that is, T/E is greater by night and A/T by day.

(3) The water-holding capacity of cylinders cut from internal tissue is less at night than during the day. It parallels the behavior of A/T under all the several environmental conditions which were used in the experiments.

(4) Stomata are, in general, shut during the day and open at night. Some evidence appeared that a decrease in T/E preceded the closing of the guard-cells.

(5) The above conclusions suggest the theory that the variations in transpiring power and in secondary absorbing power are due to variations in the water-holding capacity of internal tissue. In the case of the transpiring power, the changes in water-holding capacity act indirectly by causing the closure of the stomata and directly by resisting the evaporative power of the air.

(6) The source of the energy for this resistance to the evaporative power of the air may be traced to the imbibitional forces of colloidal gels and the cellulose walls, and hence to surface-tension forces.

(7) The effects exerted by light intensity and air temperature, especially when their duration is considered, indicate that the variations in water-holding capacity of tissue are due, at least in part, to chemical changes brought about by the metabolic processes. Under "typical" conditions, a high water-holding capacity is accompanied by a low acidity, and *vice versa*. However, certain exceptions, occurring

under controlled conditions, prove that the relation is not so simple as the influence of mere changes in H-ion concentration. The regular accumulation and disappearance of many substances within the plant must be considered not only in the light of their individual influence on the water-holding capacity, but in that of their combined effect.

(8) In former experiments the author has found well-defined autonomic movements in cacti which could be traced to changes in the water-content of the plant. These changes in water-content are of such a nature that the difference between absorption and transpiration is positive for the day and negative for the night. The discovery of corresponding variations in the water-holding capacity of internal tissue traces the causes of the autonomic movements one step further.

(9) As desiccation progresses a cactus loses less and less water by transpiration until a point is reached where the total loss for 24 hours is almost zero. There is a small loss occurring during the daylight hours which is frequently entirely replaced by a gain at night. Only about one-tenth of this gain can be accounted for by hygroscopicity of the spines.

(10) The water-absorbing capacity of internal tissue from plants which have been without water for 6 months is about 5 times as great as of tissue from plants which have had sufficient water. This is true only if the absorbing capacity be based upon wet weight.

(11) The interpretation of paragraphs (9) and (10) seems to be as follows: As the plant loses water during a drought period the total mass has an increasing hold upon its water, until a balance is reached where the vapor pressures within and without the plant are nearly equal, even a gain at night taking place when the relative humidity is higher than during the preceding day. The increased absorbing capacity of the tissue would tend also to increase the pull of the roots on the soil-water, and thus perhaps change the amount of available soil-water, even though the water-content of the soil is not raised.

(12) By the above, the ability of the cactus to withstand long periods of drought is traced to its power to hold water within its tissue against the evaporative force of the air.

Experimental evidence is now being sought for the theory mentioned above, *i. e.*, that the same internal agencies influence both the transpiring capacity and the water-absorbing capacity of cacti. Joints have been taken from plants at various times of the day and night and simultaneous measurements made of their evaporating capacity and water-holding capacity. The experiments thus far show promising results, but the work has not progressed far enough to permit of the statement of a definite law. Experiments are also under way for the investigation of the relation of evaporation-rate and water-absorbing rate in non-living colloidal gels.

The Behavior of Protoplasm as a Colloidal Complex: Factors affecting the Growth of Protoplasm, by Francis E. Lloyd.

It has already been shown that the protoplast in many kinds of pollen contains no sap-vacuoles of optically demonstrable size. The evidence offered indicates that the water taken up when the pollen is placed in contact with it is solely imbibed, and that the earlier growth-period of the pollen-tube results in chief part from imbibition pressure and not from turgor. That osmotic pressure during this period is absent or negligible in quantity (as compared with imbibition pressure, optical evidence aside) is inferred from the fact that growth may take place against a surrounding medium of very high concentration (50 per cent cane sugar), and the protoplasm may even burst, preventing, by rupturing the sustaining cellulose wall, the normal attainment of size which might otherwise be possible.

Proceeding from the above inference, it has been sought to determine quantitatively what the imbibition pressure of growing pollen protoplasts might be, as well as the effect of the presence of electrolytes upon growth-rates. Pollen of *Lathyrus* was found most useful.

In distilled water the pollen may either burst very soon without measurable growth or it may produce short tubes, in exceptional instances only reaching a maximum length of about 100 microns in 2 hours. At or before this length of tube is attained it bursts at the apex and the protoplast gushes forth. A portion may be retained and live for some hours. In 10 per cent cane sugar the matter is little better, giving a maximum length of 100 microns in 40 minutes, with bursting at or before this time. A maximum growth-rate of 200 microns an hour and total growth of 640 microns were attained in 20 per cent cane sugar. At higher concentrations both growth-rate and total growth were less, but were not totally inhibited even in a concentration of 50 per cent. In 30 per cent the rate was about one-half that in 20 per cent and in 40 per cent less than 0.1 (0.07). It thus appeared that an outward pressure of the protoplast upon the cell-wall in excess of a certain quantum can not be used for effective growth. To speak more specifically, and so far as we can see at the moment, the rate at which the protoplast can build the cell-wall of the pollen-tube is a limiting factor. The total range of pressures which allow growth at a greater or lesser rate is, however, wide, as indicated by the above-mentioned cane-sugar concentrations which permit growth.

When the pollen-tubes have attained a length of 80 microns more or less, vacuolization sets in, and we may no longer attribute to imbibition pressure the chief or, at length, even the greater rôle. Until this inversion of rôle has taken place, however, the rates of growth of the pollen-tubes may be regarded as a critical index of the effects of swelling or shrinking of the protoplasm by electrolytes upon growth-rates, since it has already been shown (Carnegie Institution Year Book

for 1915, p. 66) that certain electrolytes can cause marked swelling of the protoplasm, as of such emulsion colloids as gelatine. It must be noted, however, that indirect effects may conceivably occur, such as changes induced in the structure of the cell-wall, and these must not be overlooked.

Acids (hydrochloric, nitric, acetic, citric), in concentrations within the range N/200 to N/51200 inclusive were found in no case to increase the growth-rate when combined with 20 per cent cane sugar. At the lower concentrations the rates were approximate or equal to the control. At the higher (N/200 to N/1600), growth was less and less, and bursting took place most quickly in the highest concentrations. When, however, acid (acetic) is combined with cane sugar in a concentration of 40 per cent, in which, in the absence of acid, growth occurs only slightly, the maximum growth (four times that of the control) occurred in the concentration N/6400 of the acid component. It seems clear that the acid increased the imbibition pressure of the living colloids sufficiently to enable them to overcome the contrary effect of the cane sugar—a form of antagonism not hitherto recognized. Concentration below N/6400 produced less growth, while those above caused bursting.

Of the alkalies, the effect of sodium hydrate has been studied. In combination with 20 per cent cane sugar, the rate of growth is greater at the concentrations N/800 to N/1600 than in the control and than in other concentrations. In the higher concentrations bursting occurs. That growth takes place in concentrations of alkali lower than acid may be due to the probably already present acid of the protoplast or to the possibility that the alkali acts merely on the outer protoplasmic membrane or on the cell-wall. Similar concentrations in water cause bursting, and the ready penetration of sodium hydrate has been shown to occur by means of neutral red. The result obtained, therefore, can hardly be referred to effects on the membrane alone, though it has been found, especially in the case of *Lupinus* pollen, that certain concentrations cause, in the absence of increase of growth of the protoplast, an excessive deposition of cellulose, especially within the apex of the tube. It is also evident that the failure of acids to cause increased growth in the presence of 20 per cent cane sugar is not due to poisonous effects, since the tubes remain alive, and since, at higher concentrations of sugar, growth actually takes place in excess of that in the control.

In addition to the excessive deposition of cellulose the shape of the pollen-tube may be affected. In general, the tube tends to become bulbous, or even spherical, under conditions which increase the imbibition of the contained protoplast.

The investigation of a typical salt (potassium nitrate) in similar combination with cane sugar gave no increased swelling and no increased growth-rates.

From the above it is seen that the behavior of protoplasm as a hydrophile emulsion colloid, as previously shown (Carnegie Institution Year Book for 1915, p. 66), may express itself in terms of normal activity. We have here demonstrated, on material from which turgor as a factor in growth is excluded, that the analogy between the behavior of hydrophile emulsion colloids (such as gelatine) and protoplasm in living condition in fact obtains, and that this behavior can express itself directly in alterations in growth-rate. It must, however, be noted that the concentrations are very low as compared with those which produce measurable alterations in the imbibition capacity of non-living emulsion colloids. Protoplasm is, however, a complex of such colloids whose imbibition capacities are probably different among themselves, and are at all events at present unknown.

ECOLOGY AND PHYTOGEOGRAPHY.

The Rôle of Climatic Factors in determining the Distribution of Vegetation in the United States, by Burton E. Livingston and Forrest Shreve.

A joint study of the distribution of climatic conditions and the distribution of vegetation has been in progress for eight years. The aim has been to secure a basis upon which to enter into an examination of the correlations between the distribution of climatic factors and of plants, and to ascertain some of the climatic controls which are operative in limiting distributions of vegetation and of individual species. Prior to the present year the progress of this work has consisted in the collection and elaboration of data by both of the authors. New modes of expression of climatic data, as related to plants, have been devised, and are described in the Year Book for 1915. A new subdivision of vegetational areas for the United States has been worked out, as described on another page, and some new methods of charting the relative dominance of different growth-forms of plants have also been worked out in connection with this study.

During the present year the assembling of climatic and vegetational data has been completed, the correlations which formed the object of the work have been made, and the material has been brought to an advanced stage of readiness for publication.

Some 38 climatological features have been elaborated, chiefly from the published observations of the United States Weather Bureau, using from 134 stations in some cases to over 1,000 stations in others. The number of features worked out for each of the major climatic factors is as follows: Temperature, 12; precipitation, 7; evaporation, 4; moisture ratios (ratio of precipitation to evaporation), 5; vapor-pressure, 2; humidity, 3; wind, 1; sunshine, 1; moisture-temperature indices (the moisture ratio times a temperature datum), 3.

One of the most carefully elaborated of the climatic features is the length of the frostless season, which has been determined for 1,200

stations, ranging in their conditions from the expectancy of frost on any day in the year to the invariable absence of it. The annual means have been secured for each of the major climatic factors and the annual extremes for some of them, but in the great majority of cases the climatic conditions have been determined for the growing season only. This results in bringing into comparison the conditions of a very short period in the northern parts of the United States and the conditions of a long period in the southern States. Inasmuch as the activities of vegetation are chiefly controlled by the conditions of the growing season, the distribution of the climatic conditions of the year as a whole are, therefore, of relatively small significance in an investigation of this character.

Considerable attention has been given to the elaboration of moisture ratios, owing to the significance of the relation which exists in all parts of the country between the precipitation and the rate of evaporation. The importance of this ratio has not only been demonstrated in experimental work by both of the authors, but has been shown by Transeau to be of importance in connection with distributional work. Moisture ratios have been worked out for all of the evaporation data which it is now possible to secure for the United States, and for the year as well as the growing season.

Summations of temperature have been made by four methods, the best of which is based upon Lehenbauer's work on the relation of temperature to the growth of corn. This "physiological summation" is one in which the different degrees of temperature are given weight in proportion to their influence upon growth. The older methods of summation provide for the addition of all temperatures to form a single total, without regard to the very different physiological effects of the lower and higher temperatures which are added.

The temperature and moisture factors have, in general, been given independent treatment, but an effort has been made in the moisture-temperature indices to obtain a composite expression of the moisture and temperature conditions of the various sections of the United States.

Three series of vegetational data have been secured for correlation with the climatic conditions: (*a*) the distribution of distinctive types of vegetation, or formations; (*b*) the cumulative occurrence of selected growth-forms, or anatomically similar plants; (*c*) the distribution of selected individual species. Under the first heading nine leading types of vegetation have been used: four areas of evergreen needle-leaved (coniferous) forest, deciduous forest, grassland, the transition region between the last two, and two types of desert. Under the second heading several maps have been made which show the cumulative occurrence of all species of a given growth-form, or of the commonest ones. These maps show, for example, in what part of the eastern United States there may be found the largest number of species of deciduous

trees, how this abundance shades off in all directions, and what are the outermost limits of this group of trees. In another case the range of buffalo grass is shown so as to indicate the region in which it is a dominant element in the vegetation, the region in which it is frequent, the region in which it is rare, and the limit beyond which it is not known to occur. Under the third heading have been secured the geographical ranges of a number of trees, shrubs, grasses, and other plants, selected to represent the different types of distribution common in the United States—or, in the case of certain aquatics, selected because of their independence of the moisture factors in distribution.

A total of 115 distributional areas were worked out under these three headings and drawn on large-scale maps. Overlays were made from these maps, and used in connection with climatological maps drawn to the same scale and bearing the readings of all the stations. Of the 38 climatological maps, 31 were used in this manner, and the maximum and minimum values of each factor were secured for each of the vegetational areas, making a total of 3,565 sets of values. This operation has yielded, in brief, a set of 31 climatic values for each of the 115 vegetational areas. For each type of vegetation or for each individual species it is possible to state the maximum and minimum values of each temperature, moisture, humidity, or other factor characterizing that area.

The data secured in this manner serve to show, for example, the highest and the lowest minimum temperatures recorded at any of the stations in the grassland, or Great Plains, area; or to show the highest and lowest rates of evaporation that have been found to occur in the range of the sage-brush. These maximum and minimum values are, in short, the particular intensities which seem to limit the occurrence of the particular vegetation or plant under consideration, in so far as such a geographical correlation may be taken in lieu of experimental evidence. The maximum and minimum values will be presented in tabular form, and the total range of conditions within the distributional areas will be shown in graphic form, so that it will be possible to use either of our sets of basic data in extending this somewhat preliminary investigation with respect to other climatic features and other plants or vegetational areas.

Our results have also served to indicate which of the climatic features are the most critical in determining particular cases of distribution. This phase of the investigation has been prosecuted by a comparison of the climatic and vegetational maps themselves, and by a search for the coincidence of isoclimatic lines with distributional limits. In this manner the moisture ratios have been found to show a close relation to the distribution of the leading plant formations of the United States. While certain of the temperature features appear to be critical in limiting the ranges of some of the individual species, the controls

which limit the great areas of forest, grassland, and desert appear to be best expressed in the ratio of precipitation to evaporation.

A Map of the Vegetation of the United States from a Purely Vegetational Standpoint, by Forrest Shreve.

A map showing the principal vegetational areas of the United States has been in preparation for several years in connection with the work on correlation of vegetation and climate which is described elsewhere. Repeated revisions of the map have been made whenever further materials were secured regarding it, and the latest of these has been prepared for publication.

The aim of this map has been to distinguish the various types of vegetation in the United States solely upon the basis of the collective physiological behavior and anatomical character of the dominant plants concerned. No weight whatever has been given to floristic relationships nor to any of the climatic, physiographic, and geological factors which are known to influence the distribution of vegetation. This departure from the method by which former maps of the plant life of the United States have been made has necessitated the use of original sources of information throughout its preparation. The importance of using purely vegetational data has resided in the fact that the primary purpose of the map was to serve as a foundation for correlations of the distribution of vegetation and the distribution of climatic conditions.

The chief criterion by which the plant formations of the United States have been distinguished is the character of the growth-forms comprised in these formations. The differentiation of growth-forms among plants is largely an expression of their adjustment to a particular set of water-relations. The form, structure, and foliar organs of every plant betray its water requirements, while no such visible criteria indicate its temperature requirements. It is therefore impossible at the present time to characterize large units of vegetation without neglecting the temperature requirements of the plants, an extended knowledge of which awaits further experimental work. It has been impossible in the preparation of this map to escape these limitations.

It has been found necessary, as a result of personal exploration, to subdivide the desert portion of the United States. The regions in the Great Basin and southern California are characterized almost solely by microphyllous shrubs, while the deserts of Arizona, New Mexico, and western Texas abound in succulent and semi-succulent plants. The coastal portions of California and of Texas are to be regarded as semi-desert areas, differing widely from the continental areas just mentioned. There is also a well-marked transition area between the succulent deserts of Arizona, New Mexico, and Texas and the western

edge of the grassland. All of these subdivisions of the desert are biologically distinct and merit separation in vegetational work as much as do the deciduous and the evergreen forests of the eastern States.

The Effect of Position upon the Temperature and Dry Weight of Joints of Opuntia, by J. M. McGee.

The flattened joints of the platyopuntias were held in a vertical position, either edgewise or lengthwise. Terminal mature joints of *Opuntia blakeana* were chosen to test the relation of the position with respect to sun, to the body-temperature, and dry weight. The separated joints were held apex downward by impalement upon the bulb of a thermometer, which in turn was fastened with wooden clamps in such manner that the two surfaces of the joint faced north and south and it was said to be in an "equatorial" position. The second lot faced east and west, one such double set being exposed during March, a second during June, and a third during the latter half of July. The chief results may be summarized as follows:

(1) Joints of *Opuntia blakeana* in any position show temperatures above the air-temperature while exposed to solar radiation.

(*a*) The temperatures of joints in an equatorial position rise steadily till 12 m., then more slowly till 2 p. m. when the maximum is reached. After 2 p. m. the temperatures steadily decline, becoming the same as that of the air soon after sunset and then falling slightly below the air-temperature and remaining so during the night.

(*b*) The temperatures of the joints in a meridional position rise sharply after sunrise, reaching a maximum about 11 a. m. They then slowly drop until $12^h\ 30^m$ p. m., when they begin to rise again, reaching the second and highest maximum point about 4 p. m., after which they fall, at first slowly and then more abruptly, till sunset. After sunset the temperatures slowly fall below the air-temperature, as in the case of the other joints.

(*c*) Computation of the area inclosed by each curve, using the 10-degree line as a base, shows that on March 9, 1916, the number of hour-degree units inclosed by the air-temperature curve was 134.6; by the curve of the joints in an equatorial position 211.5 hour-degree units; and by the curve of the joints in a meridional position 230.8 hour-degree units. Hence it will be seen that the temperature of the joints in a north-and-south position exceeds that in an east-and-west position by 19.3 hour-degree units and the air-temperature by 96.2 hour-degree units and that in these joints the temperature effects would be accentuated. Similar computations show that on June 2, 1916, the number of hour-degree units inclosed by the air temperature curve was 273.0; by the curve of the equatorial joints 328.8 hour-degree units; and by the curve of the meridional joints 376.9 hour-degree units. The meridional joints exceed the equatorial joints by

48.1 hour-degree units of exposure, and the air-temperature by 103.9 hour-degree units.

(*d*) From the data just given, it will be seen that from sunrise to sunset the number of hour-degree units inclosed by the temperature curve for a June day is very much greater than the number for a March day, and that the increase is greater in the case of the meridional joints than in that of the equatorial joints. The numbers of hour-degree units inclosed by the curves of the meridional joints for March 9 and for June 2, 1916, differ by 146.1 hour-degree units; the numbers inclosed by the curves of the equatorial joints differ by 117.3 hour-degree units; and the numbers inclosed by the cuves of the air-temperatures differ by 138.4 hour-degree units.

(*e*) The loss of weight from February 28, 1916, tó April 5, 1916, of joints in a meridional position was 18.59 per cent, the loss of weight of joints in an equatorial position was 16.30 per cent, and that of shaded joints was 5.79 per cent, whereas the loss of weight from May 15 to June 28, 1916, of joints in a meridional position was 24.70 per cent, that of joints in an equatorial position was 26.23 per cent, and that of shaded joints was 23.32 per cent. The dry weight of joints similar to those used in these observations was 16.15 per cent on March 8, 1916, and had increased to 17.70 per cent on April 5, an increase of 1.55 per cent; whereas the dry weight of joints on May 17 was 29.37 per cent and had increased to 36.38 per cent on July 10, 1916, an increase of 5.01 per cent.

(*f*) The maximum temperatures reached by joints growing under natural conditions were found to be 53.0° C. on July 24, and 55.0° C. on July 25, 1916. These temperatures are higher by several degrees than those reported by Askenasy or Ursprung for succulent plants such as *Opuntia*, and it is interesting to note that Pfeffer states that "Prolonged exposure to a temperature of from 45° C. to 46° C. kills most Phanerogams" (Pfeffer's *Plant Physiology*, vol. 11, p. 226).

On the Relation between the Rate of Root-Growth and the Oxygen of the Soil, by W. A. Cannon.

It is now known that the perennials of the Tucson region associated in the same habitat, or growing under apparently similar conditions, may be subject to an environment which in many particulars is unlike. This follows from possible differences in root-habits. Thus, the cacti have roots lying within a few centimeters of the surface of the soil, while *Prosopis*, for example, forms roots which may reach to comparatively great depths. Among the environmental differences to which such widely different root-types are exposed are those of soil-moisture, soil-temperature, and aeration.

A study of the response of the leading types of root-systems to the *environmental factors of the soil has been made with the object of*

estimating their influence as determinants of the root-system types themselves. It is believed that such unlike root development is not directly due to differences in the soils or variation in the soil-moisture as the various root-types may be developed in soils that are uniform and suitably moist throughout. It is concluded, however, that the widely different root-types are in the main the direct response of the roots to temperature, and to a less degree perhaps to the variation in the composition of the soil-atmosphere which is associated with differences in depth. To test the latter hypothesis, experiments have been carried out on the roots of *Opuntia* and *Prosopis*, in which they were exposed, at known soil-temperatures, to atmospheres of known but different composition. The atmospheres used were composed of pure carbon dioxide, or of carbon dioxide to which atmospheric air had been added in known amounts.

The experiments showed that the composition of the soil-atmosphere, as well as the length of the exposure, were alike important. Exposure of both *Prosopis* and *Opuntia* for a period of 15 minutes to pure carbon dioxide did not alter the growth-rate as observed hourly. An exposure of the roots of both species to pure carbon dioxide to periods over 30 minutes, however, inhibited growth during the time of the exposure. Exposures were made up to 3 hours. Growth of the roots was renewed soonest after the shortest exposures, sooner in *Prosopis* than in *Opuntia*, and sooner in both species at high than at low soil-temperatures. In general, a longer time was required to bring about cessation of growth in the atmospheres with an admixture of air than in oxygen-free atmospheres, and recovery was soonest in atmospheres most rich in oxygen. Also, the roots of *Prosopis* recovered their usual growth-rate sooner than did those of *Opuntia*. It would appear, therefore, from the experiments, that the response of the roots of *Opuntia* to a diminished oxygen-supply of the soil is such as would tend to prevent deep penetration, and thus to support the effects of the relatively high temperature characteristic of the upper soil-layers in bringing about the formation of a superficial type of root-system. On the other hand, the reaction of the roots of *Prosopis* to a diminished oxygen-supply in the soil-atmosphere indicates that poor aeration, or a comparatively small proportion of oxygen in the soil, does not operate as a factor limiting the penetration of the roots of the species.

Rate of Root-Growth of Covillea tridentata in relation to the Temperature of the Soil, by W. A. Cannon.

It has already been shown (Carnegie Institution Year Book for 1914, p. 93), that there appears to be a causal relation between the depth of root penetration in *Prosopis velutina, Fouquieria spendens,* and *Opuntia versicolor* and the response of the roots of these species (as shown by the rate of growth) to the temperature of the soil. It will be

suggested in this place that similar relation is probably to be found in *Covillea tridentata*, the depth of penetration of the roots of which is fairly intermediate between that of the roots of *Prosopis* and of the other two species mentioned.

The roots of *Prosopis* have a comparatively rapid growth-rate and those of *Opuntia* a comparatively slow growth-rate at relatively low soil-temperatures. For example, at soil-temperatures ranging between 12° and 19° C., in 72 hours the root of a young *Prosopis* increased 22.5 mm. in length, while a root of a young *Opuntia* grew only 6 mm. under the same conditions. Relatively low soil-temperatures, therefore, do not constitute a factor limiting root-penetration in *Prosopis*, while they do in *Opuntia*. A study of the reaction of the roots of *Covillea* to soil-temperatures shows that the root-temperature relation in this form is unlike that in either of the other species mentioned.

The rate of growth of the roots of *Covillea tridentata* is relatively slow at all soil-temperatures, particularly at those that are comparatively low. Thus, at soil-temperatures between 15° and 20° C., the average rate of root-growth in young plants is about 0.12 mm. hourly; between 20° and 25° C. it is about 0.16 mm. an hour; between 25° and 30° C., the hourly rate is about 0.31, and between 30° and 35° C. it is approximately 1.6 mm. It appears, therefore, that at parallel soil-temperatures the growth-rate of the roots of *Covillea* is intermediate between that of the roots of *Prosopis* on the one hand and of *Opuntia* on the other. It is therefore probable that in the case of *Covillea*, low soil-temperatures do constitute a factor which limits the penetration of the roots.

Root-Growth of Introduced Desert Plants at Carmel, by W. A. Cannon.

Species native to the daya region of Algeria, the Mohave Desert of California, and the vicinity of the Desert Laboratory in southern Arizona have been growing in the experimental plots at the Coastal Laboratory from one to five years for the purpose of placing under observation the effects of the cool, equable climate of Carmel on their growth, especially on the growth and development of the roots. The plants studied in this connection consisted of *Opuntia basilaris* and *O. ramosissima* from the Mohave, *O. versicolor* and *Prosopis velutina* from Tucson, and *Pistacia atlantica* from Algeria.

The three regions from which the species came may be characterized as warm temperate with rain in winter only (Mohave and Algeria), or rain both in winter and in summer (Tucson). Such climatic conditions are to be contrasted with the fairly humid climate of Carmel, with relatively little difference in air-temperature between summer and winter and with rains in winter only. In the regions with winter rains the growing-season is in late winter or early spring, when the

soil is relatively cold, but at Tucson it is in midsummer as well. In the latter region, in fact, the season of most active root-growth is in summer, when the soil is relatively warm as well as moist. Whether any species characteristic of either of these regions will grow in the other regions depends largely, therefore, on the temperature of the soil at the time it is suitably moist, since an appropriate soil-temperature is a condition indispensable to an effective rate of growth of roots.

The following summary gives the maximum and minimum temperatures of the soil at the Coastal Laboratory for the summer in 1916 and for the depths indicated:

Depths.	June.		July.		August.	
	Max.	Min.	Max.	Min.	Max.	Min.
	° *C.*	° *C.*	° *C.*	° *C.*	° *C.*	° *C.*
60 cm.	16 6	14.7	18.6	17 5	18.3	17.7
30 cm.	17.2	15	18 6	17 5	20	17.2
15 cm.	27 7	15	28 6	19 4	27 7	18.3

It should be said that at the depth of 30 and 60 cm. the soil in midsummer at Carmel is moist, but at the least depth it is air-dry at that time; at all depths, owing to the sandy nature of the soil, it is well aerated.

The types of root-systems represented by the species referred to are the specialized superficial type of the cacti and the deeply penetrating type of *Prosopis* and *Pistacia*. Under natural conditions the roots of the cacti, for the most part, lie within 5 to 10 cm. of the surface of the soil and extend away from the central axis as far as 1 to 3 meters or more.

Growing in the soil of the garden at the Coastal Laboratory the Opuntias, from whatever region, tend to form generalized root-systems. Specimens which had been over two years at Carmel had formed root-systems which may be described as constituting a tuft of approximately equal length, none of which exceeded 25 cm. These took a downward as well as an outward course in their growth. However, most of the roots were confined to the uppermost 15 cm. of soil, or that stratum where, as the accompanying table indicates, the soil temperature is the highest.

The specimens of *Pistacia*, five years from the seed, had shoots about 25 cm. in length. The root-system was dominated by a tap-root which was traced down over 105 cm. There were deeply penetrating laterals also, and within 15 cm. of the surface of the soil many short, fibrous rootlets had been formed.

The *Prosopis* observed were seedlings one year old. The seed was sown in September. In the following May the roots were seen to have

penetrated to a depth of about 80 cm., and in the following August a depth of 1 meter was attained. The shoots were approximately 6.5 cm. in length a year after the seed was sown.

The results observed in the outdoor cultures, therefore, confirm the results of laboratory experimentation. Numerous tests have indicated that the roots of cacti from the Tucson region and from the Mohave grow comparatively slowly at soil temperatures below 20° C. The factor limiting root-penetration in these forms at the Coastal Laboratory, consequently, is the relatively low soil-temperature that obtains at that place. On the other hand, it has been seen in many experiments that the roots of *Prosopis* have an effective rate of growth at temperatures under 20° C., although the optimum, as in the case of the cacti, is much above this. The soil-temperature at depths thus far studied is well above the minimum for root-growth of *Prosopis*. We find, accordingly, that the roots of this species penetrate the soil at Carmel relatively deeply.

From the observed behavior of the roots of *Pistacia* at Carmel it is concluded that the temperature reponse of the roots of the species is similar to that of the roots of *Prosopis*. Thus, it is because the roots of *Pistacia* have a fairly active growth-rate at relatively low soil-temperatures that in their proper habitat they penetrate to the soil horizon carrying moisture throughout the year. The characteristic temperature reaction of the roots of *Pistacia*, therefore, constitutes a vitally important adjustment of the species to its difficult environment.

Relation of Soil Aeration to Plant-Growth, by B. E. Livingston and E. E. Free.

In this report for 1915 announcement was made of experiments on the amount of oxygen necessary for the roots of *Coleus* growing in soil.[1] These experiments have been continued with an improved and simplified technique and tests have been made also of heliotrope (*Heliotropium peruvianum*), oleander (*Nerium oleander*), and swamp willow (*Salix* sp.). Heliotrope is found to resemble *Coleus* in requiring the maintenance of a certain oxygen-content in the air of the soil. The roots of oleander also require oxygen, but appear to need much less of it than do the roots of *Coleus* and heliotrope. Also the injury produced by entire deprivation from oxygen is much less quickly developed. The roots of the swamp willow appear to be unaffected by oxygen deprivation. Plants grown in soil the atmosphere of which contained no oxygen showed normal behavior and growth over periods as long as 10 weeks. It appears that plants of different species may differ widely as to the oxygen required by their roots. Together with the work of Cannon, reported in preceding paragraphs of this report, this indicates that soil aeration is probably a much more important ecological factor than has been suspected.

[1] Carnegie Inst. Wash. Year Book for 1915, pp. 60–61.

Osmotic Concentration of the Tissue Fluids of Desert Plants, by J. Arthur Harris.

The studies on the relationship between the physico-chemical properties of the sap of desert plants and their local distribution, carried out in the vicinity of the Desert Laboratory and briefly mentioned in a preceding report (Carnegie Inst. Wash. Year Book for 1915, p. 81), have recently been published (Physiological Researches, vol. 11, pp. 1–50, 1916). These studies were made in the period of winter vegetative activity in 1914. During the summer of 1916 Dr. Harris, assisted by Mr. William G. Leamon, devoted the months of July and August to the investigation of the sap properties of the annuals and perennials active during the summer. A series of about 300 determinations of osmotic concentration was made, based upon collections from habitats ranging from Mount Lemmon, in the Santa Catalina Mountains, phytogeographically studied by Shreve (Carnegie Inst. Wash. Pub. No. 217), to the Desert Laboratory domain and immediate vicinity, where a large part of the field physiological investigations published from this Laboratory have been carried out. In view of the differences already demonstrated in the osmotic concentration of the sap of plant species of different habitats, a comparison of the vegetations from selected points in such a gradient as that from the driest mesa and the most highly developed salt spots of the desert floor to the densely forested slopes of the higher Santa Catalinas has many obvious points of interest, both physiological and phytogeographic.

For comparison with these studies on the southwestern deserts, a series of determinations have been made from other similar as well as highly dissimilar environments. Papers on the coastal deserts of Jamaica and on the rain forests of the Blue Mountains of Jamaica, concerning which a publication has already appeared,[1] will be ready shortly. Extensive observations on the vegetation of subtropical Florida and on the mesophytic environments of the Station for Experimental Evolution, in collaboration with which three studies are being made, are also under way.

Osmotic Properties of Tissue Fluids of Parasitic Plants, by J. Arthur Harris.

In an early publication from the Laboratory appearing in the Institution series (MacDougal and Cannon, Carnegie Inst. Wash. Pub. 129) the suggestion was made (as the result of experimental studies) that a necessary condition of artificial parasitism is a higher osmotic concentration of the fluids of the plant species used as parasite. Harris and Lawrence have carried out an extensive investigation of the problem on Loranthaceous parasites in the Jamaican rain forests, and in a paper now in press have shown that in the case of plants growing under these conditions the parasite is generally but not

[1]Shreve, A Montane Rain Forest, Carnegie Inst. Wash. Pub. 199.

invariably characterized by a higher osmotic concentration of its fluids. They also show that on theoretical grounds higher osmotic pressure of the tissue fluids is not a necessary prerequisite of successful parasitism in the case of a species living under natural conditions.

A substantial beginning has also been made by Messrs. Harris, Lawrence, and Leamon in the study of the sap properties of desert Loranthaceæ.

GENETICS AND TAXONOMY.

Experimental Evolution in a Desert Habitat, by W. L. Tower.

The rebuilding operations begun in 1915 did not, as feared, produce loss in or interruption of any experiments in progress at Tucson. The mortality in hibernation was the lowest it has ever been, while the progress of the cultures during the breeding season has been highly satisfactory.

Unexpected uniformity of the physical environment in the different cages and of the progress of the cultures is given by the new arrangements, so that the entire series can now be started and come to the close of the first summer generation, all at the same time, thus facilitating the task of checking, recording, and arranging for the next generation. In past years different cultures varied from one to four weeks in their emergence from hibernation and in maturity, a fact which greatly complicated the work.

EXPERIMENTAL EQUIPMENT AT TUCSON.

The rebuilding of the entire plant, begun in 1915, was continued this year. A food-cage absolutely proof against contamination and of a capacity large enough to supply all the food needed has been erected, and as a result we had the novel experience of having a surplus of food throughout the year. The grading about the entire establishment has been completed and the top finished by a layer of 4 to 6 inches of fine crushed-stone screenings. Improved instrument shelters of substantial construction have also been erected. These improvements greatly reduce the cost of maintenance and also of operation. The time consumed in irrigation, food production, and control has been decreased to about one-fourth the expenditure in 1914, while the effectiveness of the plant is greatly increased.

INTRODUCED SPECIES OF LEPTINOTARSA.

The largest and longest-continued culture of any pure type are those of *Leptinotarsa decemlineata*, which came from stocks of known composition and reactions living in the mesophytic conditions at Chicago. Successive introductions into the Tucson conditions from the same Chicago stock all show the same progress and changes. These

cultures which have been introduced at Tucson are in their fourth, tenth, twelfth, and eighteenth generations, and all show the same uniform progressive change in their water-retaining capacity during hibernation. In no instance has it been possible to reverse this change by returning the stocks from Tucson to Chicago. Accompanying this change are behavior changes, especially to desiccation, and in rates of reaction to stimuli changes not observed in their early stages and only seen after considerable alteration had taken place. In that there is a wide range in any culture of these behavior changes it seems probable that the alteration is a gradual one, but this must be checked by close observation of future introductions.

Morphological changes in pattern, color, and size continue as noted in previous reports, and most notable are the reductions of portions of the elytral pattern and of the ventral surface. These changes are genetic, as shown by test crossings with the basic stocks, and behave as Mendelian recessives and have not regressed to the original condition by living at Chicago for two to four generations.

These alterations are of the order observed in ecological varieties in nature or in varietal states under domestication. The genetic behavior is also the same, due to "losses," thus giving "recessives" in crosses with the normal. This, while true of the morphological changes, is the opposite in the observed physiological alterations, *i. e.*, water-relation, altered behavior, which are "dominants."

MUTATING STEM STOCKS.

Two chief series of these are now carried at Tucson—one C. H. 156.8, a synthetic product of three species, *L. decemlineata, oblongata, multitæniata;* the other, C. H. 15.7, a compound of *L. decemlineata* and *multitæniata*. The manner of production has been recorded in preceding reports.

In the past year the stem stocks which were not subjected to experiment continued to breed true with little variability. In the C. H. 156.8 series only slight mutations have been produced thus far, and they are all in the elytral pattern and are of an order unknown in the parent species.

The mutating lines of the C. H. 15.7 series continued their behavior in this respect during the year. The mutants in this series are of two types: (1) recombinations of characters from the original parents, and (2) alterations of these. Of the first no new types were discovered during the year and apparently the possible array has been exhibited. More than 20 of these recombination types have been observed and are being tested out in the laboratory at Chicago. Two or three years more will be required for completion.

One interesting fact was demonstrated in the year, namely, that some of the mutants mutated, either regressively, towards the stem stock,

but not thereto, and also progressively away from the stem form, the two kinds being about equal in frequency. As far as tested, these secondary mutations are stable and homozygous.

The point of most interest in this series in the year is the increasing evidence that mutability is not a hybrid splitting. Crosses of mutating and non-mutating lines show that in F_1 mutation is a recessive, segregating in F_2 with normal non-mutating as the dominant. The results of F_2, F_3, and F_4 in this series will, it is hoped, throw much light upon the mutation phenomena in these cultures.

ECOLOGICAL ADJUSTMENTS.

As the result of accompanying changed ecological or environmental conditions in the cultures at Tucson, necessary adjustments of the cultures to the new habitat were made or the culture failed. These reactions are, in our experience, of brief duration, occupying one or two or at most ten generations, and are final; that is, the newly introduced form either can or can not adjust itself to the desert habitat, a decision made in the shortest possible time. Thus far, only savannah and mesophytic habitat species have survived at Tucson, while all rain-forest, monsoon-forest, and moist-habitat types in general have failed. In these the limiting factor is water-loss, but the critical stage varies with the species, *i. e.*, *L. panamensis* egg and first larval stages; *L. undecimlineata* in hibernation; *L. diversa* in pupation and in hibernation; *L. signalicollis* in hibernation.

In species that do meet the change adjustment has been a graduated, continuous, though often a rapid, reaction, and not a jump to the full accommodation. In the earlier generations only a few pass the critical stage, and these often with difficulty; but the descendants of those that do pass through show increasing adjustment to the new conditions until in some of our older cultures, now in F_{16} to F_{18}, the adjustment is complete as far as discoverable.

Thus far I can discover no evidence that this result is the product of an environmental selection of pure lines, and therefore a selection result; but it is due, as far as I can discover, to accidental positions or circumstances such that the surviving members, while intensely acted upon, did not receive the action of the environmental force to the extent that would eliminate them. Many accidents of time, of position, and of environmental and ontogenetic progression would give opportunity for exactly this effect.

The most conclusive and impressive experience which comes from these cultures is that accommodation or adaptation is environmentally directed and limited, and not produced internally in the organism. The "adaptation" is therefore in certain ways molded by and fitted to the environment, and not offered to the environment for selection by internal and orthogenetic forces.

EVOLUTIONARY MOVEMENTS.

Of the many activities of evolutionary import in these cultures at Tucson, which duplicate as nearly as possible conditions of evolution in nature, the chief and impressive result is that of a gradual continuous change in the population in the direction forced by the habitat, resulting in alterations, with habitudinal adjustment or adaptation. These changes in function and structure, some additions, others losses, produce gradually altered aspects and behavior of the population, are genetic and not somatic, and not reversible, as far as experience goes.

Mutations also occur as the product of complex hybrid constitution, of sharp incident external forces, and there may well be other methods of origin of many mutant types, which may and do become progenitors of specific isolated groups. Populations, apparently, do not change suddenly, but rather by slow accommodation to changed conditions.

Transmission or Recurrence of Environic Effects in Phytolacca, by Francis E. Lloyd.

The progeny (F_1) resulting from seeds developed by abnormal green fruits of the "Tucson plant No. 1," which were reported upon while they were still young last year, have now come to maturity, and have produced inflorescences. These, though arrested by the climatic conditions, developed far enough during the present season to show that they are quite normal. The condition under examination, therefore, appears not to be inherited.

Plants (of lot No. 131) originating at Carmel, and normal as to structure of floral parts, were grown in Tucson and there produced abnormal inflorescences (see Year Book, 1915). An individual known to have behaved thus in 1915 was returned to its original habitat at Carmel in December 1915. It was grown under glass and produced three shoots. One of these bore normal flowers and accompanying structures, while the other two bore abnormal inflorescences.

It is recalled that this abnormal condition was first shown by the "Tucson plant No. 1," grown in Tucson in 1913 by Dr. MacDougal. The coincident occurrence of insect galls on this plant in 1914 suggested the possibility of insect origin in explanation of all the abnormalities observed. A shoot of this plant, protected against the approach of insects during 1915 by a suitable screen, continued to produce abnormal inflorescenses, but no galls. The two phenomena appear, therefore, to be of separate origin, while the possible inheritability of the abnormality appears to be negatived.

Experimental Cultures of Oenothera, by R. R. Gates.

The seeds for all experiments were counted and then placed in phials in water under a bell-jar and the air exhausted. In this way much air was removed from the seed-coats, but this method was not entirely satisfactory, since many of the seeds continued to float.

The seeds were then germinated between blotters at constant temperature by Miss Anne M. Lutz in the United States seed laboratory at Berkeley, California. In this way the percentage of germination was obtained in all cases. It varied all the way from 0 to 100 per cent. The seedlings were then planted in flats and the ungerminated seeds examined for embryos. The results show that, except in a few cases, no conclusions can be drawn from a knowledge of the percentage of germination and the number of empty seeds. There are also certain sources of error. For example, the seeds sometimes vary in size so enormously that it is difficult to determine whether the smallest should be counted as seeds.

Among the plants grown this year were wild species from California, North Dakota, Nova Scotia, and elsewhere, whose characters and variability were studied. A form belonging to *Oenothera hookeri* was represented by 11 cultures, each from a capsule of seeds from a different individual, collected in 1915 from the large population of oenotheras at Lake Merced, near San Francisco. The percentage of germination in these 11 cultures varied from 19.5 per cent to 100 per cent, and the percentage of empty or nearly empty seeds from 54.6 per cent to 0. The culture (No. 64) in which all seeds germinated contained originally 66 seedlings, but of these only 26 survived until they were planted out in May. The remainder died during the interval from January to May, when they were kept in a greenhouse without artificial heat. When the rosettes of the survivors developed, 20 were found to be of the ordinary broad-leafed type and 6 were very narrow, linear-leafed dwarfs. The original seeds were nearly all large and plump. It is probable that those which died contained at least as many dwarfs as the survivors, and some of the dwarfs at least must therefore have come from large, plump seeds.

The main results of these *Oe. hookeri* cultures were as follows: 9 of the 11 families were relatively uniform, while 2 produced markedly aberrant mutant types. One of the latter families was mentioned above; the other (No. 63) contained 63 plants, representing 4 rather well-marked types. Type (1) was the normal broad-leafed rosette (37 plants); type (2) the linear-leafed dwarf found also in culture No. 64 (5 plants); type (3) narrow-leafed and clearly marked (13 plants); type (4) rather narrow-leafed, paler green, smaller and more compact rosettes, these shading into the broad-leafed condition (8 plants). The appearance of these strikingly aberrant types, many of which have since come into bloom, in *Oe. hookeri*, was all the more unexpected, as my previous cultures of this species had proved very uniform. Some of the remaining families contained plants, all of the broad-leafed type above mentioned, although they numbered hundreds of individuals. This shows that individuals which were externally alike may breed true or may produce a large percentage of aberrants. The remaining families, although by no means uniform in all their characters, were in

some cases constantly different from each other in such features as depth of green in the foliage and predominatingly red or green midribs. These experiments throw an interesting light on the amount of diversity which may be found by growing the offspring of different individuals of a species occupying the same locality.

Another experiment yielding results of considerable interest is a series of F_3 families from *Oe. rubricalyx* × *biennis* and the reciprocal. They are for the most part essentially uniform in foliage and pigmentation, having the red buds of *rubricalyx* and foliage intermediate in character but nearer the *rubricalyx* parent. The inheritance of the difference in flower-size, between *rubricalyx* having large flowers (petals about 40 mm. in length) and *biennis* having small flowers (petals about 20 mm. in length), is very striking. There is (1) segregation in flower-size between different individuals. In the majority the length of petals is near 25, 30, or 35 mm.; but in certain plants they are as small as in *biennis* or (more rarely) as large as in *rubricalyx*. Occasionally they far overstep the size of the smaller parent and plants have been found whose petals were all as small as 10 to 12 mm. in length. In addition to this type of segregation there is often (2) striking segregation of flower-size in the same plant. For example, the average length of petals in 9 flowers blooming on the main stem during a period of 8 days was respectively 30, 20.75, 17.75, 31, 15.25, 15, 19.25, 28.5, and 31 mm. Furthermore (3) in some cases there is striking segregation, if such it may be called, in the length of petals of the same flower. In rare cases the longest petals of a flower may be twice the length of the shortest. In one extreme case the lengths were respectively 18, 20, 15, and 12 mm. Usually, however, the difference in length of the petals of a flower is less. When it is large it is frequently accompanied by irregularities in the shape or in the color development of certain petals. It is rather surprising to find somatic segregation occurring on such a large scale.

One other result which may be mentioned is the F_1 hydrid *Oe. hewettii* × *rubricalyx*. *Oe. hewettii* is a relative of *Oe. hookeri* described by Cockerell from Colorado. The parent strain used in the cross had red stems and green buds, while *Oe. rubricalyx* has red buds and more green stems. There are many other differences, such as width of leaf and character of pubescence. The F_1 hybrid is essentially intermediate in all its characters but two, the red buds of *rubricalyx* and the heavy pubescence of *hewettii* being dominant.

Relationships and Distribution of the Cactaceæ, by N. L. Britton and J. N. Rose.

The taxonomic investigation of the cactus family (by Dr. J. N. Rose and Dr. N. L. Britton) has proceeded uninterruptedly during the year and much progress has been made. The work has been mostly in the greenhouses, museums, and herbaria at New York and Washington, in the preparation of manuscript and of illustrations for the

monograph. Dr. Britton carried out field investigations on the Isle of Pines and in northern Cuba during the early part of the year, and Dr. Rose intends to visit the northern coast of Venezuela in the autumn.

The first volume of the monograph will include descriptions and illustrations of the two tribes Pereskieæ and Opuntieæ. It is expected that the second volume, the Cereæ, will include descriptions and illustrations of the two subtribes Cereanæ and Hylocereanæ; the third is designed to include the three subtribes, Echinocereanæ, Echinocactanæ, and Cactanæ, while the fourth will probably comprise the three subtribes Coryphanthanæ, Epiphyllanæ, and Rhipsalidanæ. Manuscript and illustrations for all the volumes are largely prepared.

If expeditions to Venezuela and to Paraguay, southern Brazil, and northern Argentina are successfully carried out, the only extensive cactus region little known to us will be that of Ecuador.

Improvement of Guayule, the Desert Rubber Plant, by W. B. MacCallum.

Much of the interest in the desert rubber plant, *Parthenium argentatum*, has centered at the Desert Laboratory since the publication by the Institution of Professor F. E. Lloyd's book on this wild plant. The volume in question,[1] Guayule: A Rubber Plant of the Chihuahuan Desert, embodies the results of an organized attempt to bring under cultivation a hitherto feral desert plant, together with an extensive ecological study of the same under normal and cultural conditions. Careful consideration is given to the question of rate of growth and reproduction of the guayule in its native habitat, and a large body of pertinent data is given. The various conditions of climate, soil, vegetational environment, and parasitism affecting the plant are presented in this connection. The life-history, habit, and anatomical and histological structure of the wild and cultivated forms are minutely described and compared, in order to secure exact knowledge concerning the relation between growth and the rate of rubber secretion.

The wild shrubs are collected in great quantities in Mexico and the rubber, which grades much lower than Para, is extracted by such simple processes as to make it a very profitable operation. The task of developing methods of cultivation has now been successfully accomplished by Dr. W. B. MacCallum and in making a genetic analysis of the plant he has established the fact that it includes a large number of elementary species which do not readily interbreed.

The company under whose auspices the experiments in cultivation were carried out has purchased 7,000 acres near Tucson, and guayule is now being established on this land. This effort is notable in that it is a successful attempt to bring a wild plant under profitable cultivation, and that it is the only rubber-producing plant within the borders of the United States.

[1]Carnegie Inst. Wash. Pub. No. 139, VIII+213 pp., 46 pls., 20 figs.

EREMOGRAPHY.

The First Stage in the Recession of Salton Sea, by D. T. MacDougal.

The studies on the recession phenomena of the Salton Sea have been carried on continuously since 1906. About half of the original depth of 84 feet has been lost by the balance of evaporation and seepage over inflow and underflow. The rate of fall of the level of the water has been reduced from over 50 inches yearly to less than 40. The loss from January to April was less than the amount received from rains and from overflow of irrigation systems during the winter of 1915–16, so that the lake has now altered from a constantly falling level to an oscillating level. This and the fact that the emerging beaches are now occupied by halophytic or salt plants only are used as criteria to mark the end of the first stage of the recession.

The reduction of the total body of water from an original total of about 3 or 4 cubic miles to half that amount has been accompanied by a concentration of salts dissolved from about 0.33 per cent to 1.6 per cent. The variations in the principal constituents during the last three years are given below:

	1912	1913	1914	1915	1916
Solids	...	.	1,179.6	1,377.4	1,647.2
Water occlusion	...	...	36.2	42.2	47.5
Calcium	....	....	22.22	25.27	29.85
Potassium	..	.	4.01	5.2	5.71
Magnesium	.....	...	19.03	22.63	27.17
Chlorine	.....	....	559.66	650.95	787.64
Sulphuric (SO_4)	..	...	148.10	174.47	207.89
CO_2 total	12.09	11.28	10.68	11.92	11.40

The concentration of calcium was checked during the first few years of the recession of the lake by reason of the fact that it was being deposited as travertine as a result of the activity of a group of organisms, and it is now showing a higher concentration, the water having become too salty for the algæ and bacteria earlier concerned in this action.

The larger islands have become joined with the mainland, but Cormorant Island, originally freed from all seed-plants, is still separated by a mile of salt water from the northeastern shore. Its reoccupation by plants has proceeded as shown in the table herewith (the census for 1916 was taken in May).

Revegetation of Cormorant Island.

Pioneer species.	No. of individuals. 1908	1912	1916
Atriplex lentformis			35
Baccharis glutinosa			
Crypanthe barbigera			1
Distichlis spicata			1
Erigeron canadensis			2
Heliotropium curassavicum			15
Lactuca asper			2
Pluchea sericea			4
Rumex berlandieri			1
Sesuvium sessile		2	5
Spirostachys occidentalis		20	404
Total, 2 species			
Total, 6 species		33	
Total, 10 species			470

The total number of species now occupying the island is probably as great as when it was a desert hill. It is to be noted that 460 of the 470 individuals on the island are salt plants, and that one of the pioneers, *Baccharis*, has already been lost.

Composition of Salton Sea Water, June 10, 1916, by A. E. Vinson.

The annual sample of the water of Salton Sea was taken June 10, 1916, over deep water off Salton Station. The results of the analysis are given in the following table:

Composition of Salton Sea Water, June 10, 1916 (in parts per 100,000).

Total solids (at 110° C.)	1,647.2	Carbonic, CO_2 (total)	11.40
Water of occlusion and hydration	47.5	Bicarbonic, HCO_3 (volumetric)	16.10
Sodium	528.9	Silicic, SiO_4	1.21
Potassium	5.71	Phosphoric PO_4	doubtful trace
Calcium	29.85	Boric acid	trace
Magnesium	27.17	Oxygen consumed	0.170
Aluminum	0.034	Nitric	None
Iron	0.060	Nitrous	Trace

From June 8, 1915, until June 10, 1916, the total solids in the Salton water have increased from 1,337.4 parts per 100,000 to 1,647.2 parts per 100,000, equivalent to a concentration of 19.6 per cent. This is the greatest annual concentration noted, except the concentration from June 8, 1909, till May 22, 1910, which was 21 per cent. Aside from the concentration of the solids collectively, there is little requiring discussion at this place. Mention, however, should be made of phosphoric acid. In the early annual analyses of the series weighable amounts of yellow precipitate were obtained. For several years the phosphoric-acid test remained positive, the test being made by scratching the sides of the beaker with a stirring-rod, but at this time no unmistakable reaction can be obtained from 3 liters of water. Phosphoric acid, therefore, has been reported as a doubtful trace.

Climatic Investigations, by Ellsworth Huntington.

During the past year two important steps have been taken in the study of climatic changes. In the first place, the work begun in 1903 by the Pumpelly expedition to Transcaspia and described in publications Nos. 26[1] and 73[2], together with later investigations in the western hemisphere, as described in Publication No. 192[3], has now been summed up in a volume entitled "Civilization and Climate." This not only gives a résumé of the entire problem of climatic changes during historic times, but adds hitherto unpublished data derived from last year's work in the Mohave region. It also considers the effect of various conditions of climate and weather upon human energy.

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[1]Pumpelly, R., Ellsworth Huntington, et al. Explorations in Turkestan, with an account of the Basin of Eastern Persia and Sistan. Expedition of 1903. Carnegie Inst. Wash. Pub. No. 126.

[2]Pumpelly, R., Ellsworth Huntington, et al. Explorations in Turkestan, Expedition of 1904. Carnegie Inst. Wash. Pub. No. 73.

[3]Huntington, Ellsworth et al. The Climatic Factor, as illustrated in Arid America. Carnegie Inst. Wash. Pub. No. 192.

During the past few years the daily work of some 15,000 students and factory operatives has been tabulated. The results lead to the conclusion that human energy is more closely dependent upon climate than has hitherto been supposed. It also appears that to-day civilization and climatic energy bear a surprisingly intimate relation. Furthermore, the final analysis of the evidence obtained last year in the Mohave Desert leads more strongly than ever to the conclusion that the climate of the past has been extremely variable and that the variation has consisted essentially of changes in the distribution and number of cyclonic storms. Thus there is reason to think that in the past civilization and climatic energy were as closely associated as now.

The second important step in the study of climate during the past year arose in part from the work in the Mohave Desert during 1915 and in part from the suggestive writings of M. A. Veeder. In the Mohave work the wonderful series of salt lakes and dry basins from Owens Lake to Death Valley emphasized the conclusion set forth in Publication 192, that changes of climate not only are more important and more rapid than has hitherto been supposed, but that there is no break between small variations visible within a single lifetime and the great variations of the glacial period. In other words, there seems to be growing evidence that a study of present climatic variations furnishes the key to those of the past.

The other conclusion from the lakes of the Mohave Desert was that variations in the strength of the wind have been one of the most important factors in producing climatic changes. As far back as 1888 Veeder suggested that changes in electrical activity of the sun from day to day, as evidenced in the variations of sun-spots, give rise to variations in barometric pressure and thus in winds and rains. This hypothesis in connection with the huge beaches which seem to have been formed in former times by the action of phenomenally strong winds around Owens Lake, for example, led Dr. Huntington to undertake a mathematical analysis of the relation between sun-spots and barometric pressure. Instead of using the actual sun-spot numbers, as has been the almost universal custom, the change in spottedness for each day was computed. A new method was likewise employed to compute the barometric pressure. The problem was to determine the strength of the wind-producing forces. Therefore, instead of using extremes or averages, as is commonly the case, an actual count was made of the number of isobars crossing every fifth degree of latitude and every tenth degree of longitude.

Both the solar and terrestrial data have been computed for each day for seven years. The two sets of figures have been compared by a method of correlation coefficients. Since the day and month are the units instead of the month and year as in most investigations, a period of seven years gives results of comparatively high accuracy. There

appears to be an unmistakable relation between changes in the solar and terrestrial atmospheres. The probability of this conclusion is increased by the fact that when the terrestrial area includes not merely the United States, but also the Atlantic Ocean and Europe, the evidence of a relationship becomes much stronger.

Inasmuch as the terrestrial response follows the solar phenomena with a delay of no more than a day or two, the actuating cause can scarcely be heat. It would require far more than a day for a change in solar heat to warm the earth's surface and thereby warm the atmosphere enough to cause pronounced barometric rearrangements. Accordingly there seems ground for believing that Veeder's hitherto neglected hypothesis may be correct. According to that hypothesis cyclonic storms and other periodic barometric variations of the earth's atmosphere are not due to heat alone, but are the coordinate effects of solar heat plus solar electricity. Whether electricity or some other form of energy is the dominating cause is not yet evident, but it seems highly probable that some great factor has thus far escaped attention. If this view is correct it will demand an important reorganization of our theories of meteorology and of climatic changes throughout historical and geological times. The matter is so complex that it requires investigation on a scale far larger than has thus far been possible.

An Ancient Lake Basin on the Mohave River, by E. E. Free.

The Mohave River rises in the San Bernardino Mountain Range, on the southern border of the Mohave Desert, and flows northeastward across this desert to the "sink" of Soda Lake, where its waters now suffer final evaporation. In an earlier period the river was more vigorous and flowed through Soda Lake northward to a junction with the Amargosa River and thence to Death Valley.[1] A recent examination of Soda Lake and of the divide which marks its northern limit has confirmed these conclusions, but indicates that the amount of the overflow discharged by the river into Death Valley was surprisingly small.

The Soda Lake basin is really double, containing not only Soda Lake proper, but also Silver Lake, 10 miles to the north. Both of these "lakes" are playas of usual character. The drainage line beween them is still open and at times of extreme flood Silver Lake is still reached by the waters of the Mohave. Just north of the Silver Lake playa is the divide which now truncates the river. It is a narrow ridge of rock in place and is apparently quite ancient geologically, being far earlier than the period of greater river activity which we are considering. The lowest point of this divide is 32 feet above the present surface of the Silver Lake playa, and that this lowest point determined the overflow of a lake which formerly covered both Soda Lake and Silver Lake is proved by a well-marked beach terrace surrounding the basin at this same elevation. There is also one lower terrace which is

[1]See Huntington, Carnegie Inst. Wash. Year Book for 1915, p. 26.

distinctly marked, and there are doubtful signs of several intermediate and lower ones. Doubtless these were produced by temporary pauses in the recession of the lake.

The channel of the ancient overflow over the Silver Lake divide is clearly marked in the alluvium north of the divide, but is small. In places it is less than 20 feet wide and only 8 to 12 feet deep. Since it is cut in poorly consolidated alluvium and since its grade is ample for extensive alluvial cutting, it is impossible to escape the conclusion that the overflow out of the ancient lake was both small and transient. This is confirmed by the entire absence, so far as discovered, of any sign of stream erosion of the rock portion of the divide. No signs of any alternative overflow channel were discovered, in spite of careful search, and the topography renders it improbable that any such channel exists.

The ancient lake was the sole discharge-point of the ancient Mohave River, and the lake-level must have served as a gage of the river's volume. The fact that the overflow from this lake was so small and transient serves to confirm the conclusions, for which much other evidence is accumulating, that the geologically recent period of lake and river expansion in the North American deserts was neither so humid nor so long-continued as has usually been imagined. It is probable that during most of its existence the Mohave River has not differed greatly from its present character. A period during which it was similar to rivers of the humid regions is not to be thought of. All evidence, however, indicates the reality of the minor climatic pulsations, the existence and importance of which has been emphasized by Huntington.

Underground Structure and Artesian Water in the Desert Valleys of the Great Basin, by E. E. Free.

An incident of the investigations of desert geology and topography during the last ten years has been the accumulation of several hundred records of wells bored in the desert alluvium in search of water or for other practical purposes. Among these are the records of 15 deep holes (500 to 1,200 feet) and over 50 shallower ones which were drilled under my direction. Consideration of this accumulated data, as well as of the physiographic processes now observed to be active on the present surface of the deserts, has led to some generalizations regarding the structure of the underground portions of the desert alluvium, which generalizations are of interest especially in connection with the occurrence of artesian waters in the desert valleys. Such artesian waters have been found in several valleys and under circumstances which indicate considerable differences from the conditions existing in the older artesian areas.

It is necessary to recall the geographic character of the Great Basin as composed of a series of long mountain ranges separated by long and

comparatively narrow valleys. These trough-like valleys have been filled deeply with alluvial débris from the erosion of the bordering mountains, and it is from these alluvial deposits that nearly all of the underground waters of the region have been obtained. There being no outward drainage and very few through-flowing streams, the filling of the valleys has been done entirely by local storm-waters and by the small streams of the mountain slopes. By erosion at higher levels and deposition at lower, this process is gradually lowering the mountains and filling the valleys.

The occurrence of artesian and other underground waters in the accumulations of alluvium which fill the valley troughs appears to depend entirely on the existence of buried stream-channels. The streams which descend the mountain slopes and which have brought about the alluvial filling are extremely variable both in volume and in position. As they vary from flood to dryness, and as they migrate back and forth over the slope which they are building, they leave alternate and variable deposits of gravel, sand, and clay. Where a stream is stationary long enough to form a channel this channel will be marked by a line of sand and gravel, and when the stream moves on, floods or other streams may cover the sand-streak of this abandoned channel with finer material, even with clay. In this way there are built into the mass of alluvium many such abandoned stream-channels, all leading from the mountain-slope toward the center of the basin. Since these buried channels are of sandy and gravelly material, they are easily pervious to water. Many come to be sealed above and below by clay or by the desert hardpan called caliche. The dish-shaped or bowl-shaped contour of the valleys gives such buried channels a considerable difference of elevation between the lower end at the basin center and the upper end toward the rock wall. Usually this upper end merges into the talus of gravel and boulders which borders the mountain. It is obvious that this structure may result in artesian conditions. Water which falls as rain on the mountains flows freely through the bordering talus of coarse material and enters the upper ends of the buried channels, which offer it easy passage down the slope. Further down this slope the intercalated clay or caliche beds confine the water of the channels and an artesian pressure is developed.

It is possible to make three deductions of practical value: First, artesian water is to be expected only where this bowl-shaped structure of the alluvial fill occurs. Second, artesian water will not occur necessarily in well-marked strata or at definite depths as it does in rock artesian areas, but may occur at different depths and pressures in adjoining wells, depending upon which of the buried channels may have been penetrated; it is possible even to have entirely dry wells and productive wells side by side. Third, if a valley be divided into concentric zones outward from the center, artesian conditions will be most likely

to occur in the intermediate zones. The outer zones will not have sufficient clay or caliche seals to confine successfully the water of the channels. The inner zones will be so far from the mountains that most of the sand-streaks of the buried channels will have pinched out or been choked with clay so that they no longer serve as water conduits.

It must not be imagined that the requirement of bowl-shaped structure in the alluvial beds necessitates that the valley be an inclosed basin without outward drainage. It is true that the necessary structure and the typical artesian conditions are best exhibited in such undrained basins, but the same structure and sufficiently favorable conditions may occur also in open valleys, provided there is enough breadth and depth of alluvial fill to produce the proper contour of the underground beds. The important criterion of artesian occurrence is not inclosure of the drainage, but the slope of the valley and the breadth and flatness of the alluvial fill. In valleys which are steep or narrow the materials of the alluvial deposits are poorly sorted. All of the beds contain much coarse material and are permeable to water both horizontally and vertically. Broad valleys and slopes gentle enough to permit standing or slow-moving water are essential to the collection and deposition of clay, and the deposition of clay layers is essential to the sealing of the buried channels and the production of artesian conditions.

From the considerations outlined in the discussion one can formulate the first necessary condition for the occurrence of artesian water in the desert valleys, namely, the existence of a deep alluvial fill the superposed layers of which have the structure of a shallow bowl, flat or nearly so toward the center. Breaks in the rock wall of this bowl, allowing the escape of surface drainage, are not important, provided the stated condition is satisfied. Since the water, as in all artesian areas, must be provided by rainfall on higher land, this forms another necessary condition. In the desert valleys this means the existence around the valley of fairly high mountains, on which the fall of rain and snow will be considerable and from which the water can drain into the talus slopes and enter the buried channels. These two are the only conditions necessary for artesian occurrence.

If these criteria be applied to the valleys of the Great Basin it is obvious at once that many valleys are too narrow or too steep to have the necessary bowl-shaped structure of the underground beds. Many others have insufficient drainage areas or have watersheds of such low altitude that precipitation upon them is inconsiderable. There are, however, many desert valleys in which the necessary conditions appear to be satisfied. In several of these artesian waters have already been discovered; for instance, in the Salton Basin, California, and in the Carson Sink, the Las Vegas Valley, and Railroad Valley, Nevada. Doubtless water will be discovered in others of the valleys

when it is intelligently sought for, and in connection with this search it is possible that the considerations outlined above may prove of practical value as well as of scientific interest.

The Surface of the Painted Desert, by Godfrey Sykes.

A brief reconnaissance has been made in the so-called Painted Desert in Northeastern Arizona, supplementing cursory examinations of the same region made 25 years ago. Superficially there are some points of resemblance between this drainage area and that of the Santa Cruz which render a simultaneous examination of the two desirable. Both consist in the main of broad, open valleys, containing typical desert rivers running from southeast to northwest; both areas are comparatively arid and both are flanked by mountain ranges or high plateaus. The resemblance almost ceases here, however, since, owing to the general sandy and porous nature of the soil in the Painted Desert, eolian influences are far more potent in effecting topographical change than they are in the Santa Cruz Valley, and vegetation is much more scanty and its existence more precarious.

The region is comparatively unexplored scientifically, and should prove a most interesting one for the botanist, zoologist, and eremographer, from the fact that it consists in large part of a series of platforms or terraces, extending parallel with the Little Colorado River and isolated from each other by fairly well-defined cliffs or ramparts, each possessing very distinctive features in soil and topography.

Erosion in the Santa Cruz Valley, by Godfrey Sykes.

During the past season the work of collecting data concerning the physiography of the Santa Cruz drainage area has been carried on. As a type of intermittent desert river the Santa Cruz affords many features of the greatest interest. It has also undoubtedly served as a channel for human intercourse from the earliest times, and since the advent of the Spaniard in the Southwest its importance as such has been very great. At present it is undergoing somewhat extensive changes in the vicinity of Tucson, for it is in effect cutting through the rim of a playa-like basin or bolson, in a temporary effort to render its gradient more even. This effort has far-reaching effects upon vegetation, water-supply, and kindred matters, and is therefore of considerable scientific interest. The examination of the valley in its entirety has been hampered, however, by the chaotic conditions across the Mexican border, as, although rising in Arizona, the river makes a greater detour through the Mexican State of Sonora before assuming its main course towards the northwest.

EQUIPMENT.

The development of facilities for control of temperatures has included the construction of a glass compartment 12 by 20 feet, with an attached work-room, at the Coastal Labóratory. An attached work-room shelters the switchboards and current controls. Darkened chambers for similar purposes have also been equipped in the main building at the Coastal Laboratory and at the Desert Laboratory. These features have already demonstrated their usefulness.

The principal instrumental additions include a set of 12 auxographs designed by the Director for the purpose of recording variations in volume accompanying growth, and for measuring the swelling of colloids.

A food-cage 30 by 60 feet, inclosed with wire netting, has been constructed for growing solanums, to serve as food for the beetles used in Professor Tower's experimental work in evolution. Other changes in the equipment have consisted principally in minor replacements and repairs and minor improvements in machines and apparatus already on hand.

FIELD WORK.

The practical radius of action in the study and connotation of natural conditions has now been extended 60 to 100 miles by improvement in motor transportation. In addition to frequent excursions to such distances, some detached field parties have been sent out during the year. One party, accompanied by Dr. W. T. Hornaday, of the New York Zoological Park, traversed the region southwest of Tucson to the Ajo Mountains and north to Casa Grande in October 1915. A second party went northward through Arizona to the Grand Canyon, eastward to the Painted Desert of the Little Colorado, and southward by two different regions. A westward line was carried across the drainage of the Colorado River, the Mohave Desert, and the Coast Range to Carmel. The region between Tucson and the summit of the Santa Catalina Mountains is covered frequently. Workers at the Desert Laboratory easily visit the points of interest in an area of about 5,000 square miles, and material from this area is readily procurable for experimental purposes.

DEPARTMENT OF ECONOMICS AND SOCIOLOGY.*

HENRY W. FARNAM, CHAIRMAN.

Since the report of a year ago two histories have been published by the Institution for this Department:

1. "History of Domestic and Foreign Commerce of the United States," by Emory R. Johnson, T. W. VanMetre, G. G. Heubner, and D. S. Hanchett, vol. 1, xv+363 pages and 5 maps; vol. 2, ix+398 pages and 5 maps.
2. "A History of Manufactures in the United States, 1607-1860," by Victor S. Clark, one volume, xii+675 pages, 14 plates and charts.

"The History of Transportation in the United States before 1860," prepared by Miss Caroline E. MacGill, under the direction of Professor B. H. Meyer, has been accepted for publication and a large part of the volume is in type. The "History of the Labor Movement," by Professor John R. Commons and a staff of collaborators, has undergone a thorough revision and has been read in manuscript by the writer, but still requires some editorial work before it can be offered for publication.

In the Division of Population, Professor Willcox has been devoting about a third of his vacation to his volume, and has taken a leave of absence from university duties in order to give the greater part of his time to it during the coming academic year.

In the Division of Agriculture, Professor Taylor's study of agricultural prices from 1840 to 1860 and Professor Hibbard's history of Federal land policies have been handed in to President Butterfield, but are not yet quite ready to be offered for publication.

In the Division of Mining, Mr. Parker has been revising the manuscript which was described in our last report, and has nearly completed the period down to the Civil War.

In the Division of Social Legislation the writer has secured a study of the mining laws of Pennsylvania by Mr. A. L. Trachtenberg, which, though not prepared with the aid of a grant from the funds of the Carnegie Institution of Washington, forms one of our projected series of monographs. It is to be published by the United States Bureau of Labor Statistics. The writer has also been at work upon different parts of his own study and has taken a leave of absence from academic work for the coming year in order to gain more time for this history.

In the Division of Federal and State Finance, Professor Gardner reports that on account of lack of funds he is not having any more monographic studies written, but that he has been spending the greater part of the summer working upon his own divisional summary.

In the Divisions of Money and Banking and The Negro the preparation of monographs has ceased for the present, and on account of other duties the heads of these divisions have been unable to give much time to their work.

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For reasons stated in earlier reports, the work of the Division of Industrial Organization has been suspended for several years and a large part of the balance of its original allotment has been transferred to other divisions in order to hasten the completion of their tasks.

Of the Indices of State Documents no further volumes have been issued since our last report, but Pennsylvania is in press and should be published soon. Progress has also been made upon South Carolina, though the inaccessibility of much of the material is making the work exceptionally difficult. When this State is completed, Miss Hasse hopes to finish the rest of the thirteen original States by taking up Connecticut, Maryland, Virginia, North Carolina, and Georgia; the unexpended balance of her special appropriation should be sufficient, on the basis of the cost of the volumes already finished, to index these States.

The list of those already issued or well-advanced is as follows:

California	1908	New Jersey	1915
Delaware	1910	New York	1907
Illinois	1909	Ohio	1912
Kentucky	1910	Rhode Island	1908
Maine	1907	Vermont	1907
Massachusetts	1908	Pennsylvania (in press).	
New Hampshire	1907	South Carolina (in preparation).	

In conclusion, I desire to call attention to the need of a reorganization of this Department. This was proposed in the annual report for 1911, and has been repeated annually since that time. There is little to add to the arguments presented in the report for 1915, except that they gain new force with each year's experience (Year Book No. 14, p. 110). The need is hardly questioned by anyone. The difficulty lies in working out the details, and the writer will be glad to render such assistance as may be desired to reach a satisfactory solution of the problem.

In all matters of this kind it is wise in planning for the future to clearly understand the past. It may, therefore, be helpful at this time to review briefly the history and aims of the department from its inception, in order that, if the Trustees should decide upon a reorganization, they may see the work as a whole in a better perspective than can possibly appear in the report of a single year. The proposal to study intensively the economic history of the United States was originally made by an advisory committee consisting of the late Colonel Wright, Professor Clark of Columbia University, and the writer, and was explained by Colonel Wright in an address delivered at the annual meeting of the Economic and Historical Associations in 1904. It was realized by us all at the beginning that the field was vast; that it could be dealt with adequately only by first preparing a solid foundation of special monographic studies; and that a large number of these would be required in each of the twelve sections into which the work was divided. For example, in order to treat the subject of State finance thoroughly, we should have as a preliminary the financial history of each of the 48 States. In the Division of Manufactures we should

have each of the leading branches of manufacture treated intensively. In some divisions the nature of the subject-matter involves fewer of these studies than in others, but it was evident that in the aggregate a large library of monographs would have to be created if we were to cover thoroughly even the leading topics blocked out in our schedule. To carry out such a project on a commercial basis, and pay an adequate compensation for the time of workers, would have involved a prohibitory expense. Hence we adopted the plan of asking the cooperation of scholars belonging to the two associations most immediately concerned and of proposing to give a small allowance to cover the traveling and other expenses of such competent graduate students as would select for their doctoral theses subjects from our schedule of monographs. This was an altogether economical and, in the opinion of the writer, a wise procedure, since we were able to secure our studies at slight expense. The work was, it is true, done by relatively young men, but it was done under the supervision of professors in the various universities by men of promise, not a few of whom have subsequently made honorable records as economists. In time it became evident that there was much valuable material in the public documents of the several States which was inaccessible to scholars except at great labor. Hence it seemed desirable to prepare an index of economic material found in these publications, and we began the indices to State documents, of which 12 numbers have now been issued in 13 volumes.

We all realized from the beginning that the work would be slow. In the initial report of the advisory committee made in 1902, which asked for an annual appropriation for five years, it was distinctly stated that this was intended to be provisional only. In the early reports of Colonel Wright the same thought occurs repeatedly. Thus, in his report for 1906, he said: "As the investigation goes on the sources of original information develop, and of course the work of collection increases," and he added: "the time may be longer than we at first anticipated." (Year Book No. 5, p. 158.)

The work was slow, not only on account of its extent but also on account of the difficulty of securing workers. We have not yet the body of trained scholars in our country that older countries like France and Germany can command. Repeatedly men have begun a piece of work and then dropped it, because they were offered positions as teachers or some other lucrative employment. To give a single instance of what has happened frequently, the study of mining legislation in Pennsylvania, mentioned above in this report, had been undertaken and abandoned by two different men before a scholar could be found to carry it through to completion. Hence in the first five years we had not drawn more than a part of the appropriation originally granted. Indeed, we have not yet exhausted it.

The magnitude of our task and the consequent necessity of taking ample time for its completion have been recognized by competent impartial observers. Thus Professor von Schmoller, one of the most

distinguished of German economists, refers to our work in an important article contributed by him to the "Handwörterbuch der Staatswissenschaften" (vol. VIII, pp. 453–454). He describes Professor Commons's Documentary History as "an exceedingly valuable publication of documents." Regarding the more specific task of this department, he says: "In twenty-five years a monumental work in economic history will have been created such as hardly another country possesses." Similarly the late Professor Callender, in an article on American economic history published in the *American Historical Review* (vol. XIX, No. 1, p. 94) says:

"The immediate need is for the same careful, painstaking study of economic activity which historians have given to political activity. We are fortunate in possessing in the Department of Economics and Sociology in the Carnegie Institution of Washington a well-organized and subsidized enterprise designed to accomplish precisely this work. For a decade it has been stimulating investigations by grants of money and seeking to initiate and guide them by its organization. To a large extent it is responsible for the work which has been done during that period, and a glance at the results of its activities affords striking evidence of the progress that has been made."

He then gives some general facts regarding our monographic work and outlines the three important types of special study which ought to be multiplied in order to prepare the way for an economic history of the country. In examining how far these types have been developed he points out many topics not yet treated and says (pp. 96–97):

"It is clear from this brief survey that the work of investigation needs to be carried much further and to be systematized so that the most important subjects shall receive most attention. It is to be hoped that the Carnegie Institution will not relax its efforts to stimulate and direct such work. A closer organization of the collaborators, with a more definite plan of the work which they are seeking to produce, would be likely to secure more valuable results."

Upon the death of Colonel Wright, February 20, 1909, it became necessary to fill his place, and the future of the Department was considered at a conference with the President of the Institution. The collaborators were now informed that the Carnegie Institution was not in a position financially to make any considerable additional appropriations towards the work. It also appeared that the trustees expected to have the whole completed in a much shorter time than had been thought possible by Colonel Wright and his colleagues. Moreover, the form of organization which had been adopted by this Department was very different from that which had become the standard in other Departments. It should be said here that this organization has the defects of its qualities. It is economical in that it enables us to secure the advice and services of specialists without paying them salaries. On the other hand, it lacks responsibility and permanence. These defects became more pronounced in the course of time, as several of those who had undertaken the direction of divisions were called upon to assume new duties and thus found themselves

with less available time to give to the work of the Institution, while the active membership of the board automatically shrinks whenever one of the twelve collaborators completes the work of his Division.

The problem which confronted the writer when he was chosen to succeed Colonel Wright as chairman of the Department was, therefore, a difficult one. The original plan of laying very broad foundations and devoting many years to the work did not seem to be acceptable to the Trustees, nor was the form of organization ideal; and yet, if we had disbanded the board of collaborators, it would have been very difficult for the Department, even though reorganized on a plan intrinsically more effective, to utilize the work already done. For it should be remembered that, in addition to the large number of formal monographs, some of which have been published and some of which are still in manuscript, each collaborator has accumulated a great mass of notes and studies which clearly can be utilized only by him. Under the circumstances the best plan seemed to be to pool our funds and, by transferring money from those divisions which had relatively large balances to those whose work was most susceptible of being hastened, to get some, at least, of the divisional reports completed. This is the task to which the writer has been devoting himself for the last seven years. In order to make the funds go as far as possible, he has drawn no salary for himself, nor has he even charged for the time of his secretaries, and the fund set apart for administration has therefore carried only such minor items as postage, stationery, printing, and occasional traveling expenses. The administration expenses, which in the six years down to 1909 amounted to $7,474.47, have been in the last seven years $1,640.44, or an average of about $234 per year. This policy has enabled us to transfer from the administration to the research departments the sum of $8,550.

Besides the funds obtained by transfers, the trustees have made additional appropriations for the purpose of paying salaries to such of the collaborators as might be able to take a leave of absence from their regular occupations and devote themselves exclusively for a period to the work of the Institution. In this way we have succeeded in completing the more comprehensive histories enumerated at the beginning of this report in addition to the foundation work represented by the volumes of the Index, some 136 monographs, published and unpublished, and over 100 magazine articles enumerated in our bibliography. But our unexpended balances are now so small that some decision with regard to the future is urgent. This involves an answer to three specific questions:

(1) Shall the department be reorganized with a salaried head to harmonize with other departments?

(2) Shall work upon the Contributions to American Economic History be continued, or shall we conclude the series after the publica-

tion of the manuscripts which are now completed or can be completed in the near future?

(3) Shall the Index be continued?

These last two questions are related to, but not necessarily dependent upon, the answer to the first. The establishment of a department with a salaried staff would not of itself lead to the discontinuance of the Contributions or of the Index. The present collaborators or their successors might continue to supervise the preparation of monographs or work out their own divisional summaries in a relation not unlike that of the research associates in other fields. Some such arrangement as this seems desirable, if we are to utilize the mass of material already accumulated. We must recognize the fact that the speed with which different divisions can be completed will inevitably be very different, partly on account of the varying difficulty of the subject-matter, partly on account of the personal equation of, and the competing responsibilities resting upon, the heads of divisions.

The writer's experience during the past dozen years has not weakened in the least, but has rather strengthened, his conviction of the importance of the undertaking. Since we began our work, not a few books in American economic history have been published by writers under the influence of the Marxian doctrine of class conflict. According to this familiar socialist maxim, all history is but a series of conflicts between economic classes, each seeking its advantage at the expense of others. Some of these writers have analyzed the economic interests of the leading men in our public life, and of political parties, and have endeavored to explain historical events by tracing them to material and egotistic motives. That these studies are of interest can not be denied, but any author who undertakes historical or scientific research under the bias of a philosophical theory can hardly fail to make such a presentation of facts that they will confirm his theory. It has been the aim of this Department to be strictly objective, and while individuals may err in their understanding and their interpretation of the facts, if they are animated by the scientific spirit their work will have an authority which can not be possessed by the work of those who write with a theory to prove.

Our studies in economic history also have an important bearing upon practical questions. In these days of rapidly increasing governmental regulation of business and labor, the one safe guide is the experience of the past. In this field it is believed that our contributions will be of great practical importance, and that the past has many more lessons for us than has been hitherto realized.

The writer therefore hopes that means may be found to continue at least the more promising divisions of the Contributions and of the Index and at the same time to give the Department a more effective organization.

DEPARTMENT OF EMBRYOLOGY.*

FRANKLIN P. MALL, DIRECTOR.

The following report deals for the most part with studies in embryology that have been published during the past year. The subjects may be grouped under three headings: cytology, human embryology in general, and neurology.

CYTOLOGY.

The work accomplished in the last ten years in the field of cytology has gone far to improve our knowledge of the structure of the protoplasm, from the fact that it has cleared the field of several theories and at the same time has harmonized others which seemed to be irreconcilable. In the study of the embryonic protoplasm with the special technique required, one of the most important advances has been made. This work—started by Meves on the embryos of birds and extended to mammals, amphibians, invertebrates, and, during the past winter, to fishes by Professor Jules Duesberg—has given harmonious results. It has been shown that the cytoplasm of the undifferentiated cell, in addition to the centrioles and the more or less abundant and non-permanent yolk granules, contains a ground-mass in which bodies of various and changeable form, the chondriosomes, are embedded. It is in these undifferentiated embryonic cells that investigators have found the chondriosomes the easiest to define by utilizing their chemical as well as their morphological properties. A careful study of the behavior of the chondriosomes during the evolution of the cell has shown that they are able to move, apparently freely, in the surrounding mass, and consequently that such things as a reticular structure of the protoplasm and an alveolar structure in Bütschli's sense (whose theory, by the way, is very much open to criticism from the physio-chemical point of view also), most probably do not exist. The field has furthermore been cleared of the so-called "chromidial" theory—the chondriosomes belong to the protoplasm. As already stated, the chondriosomes appear in various forms, sometimes as granules, sometimes as filaments which may be branched or even connected in a network, or, at other times, as one large body. This is frequently the case in the spermatid of invertebrates. Again they assume different shapes in the various phases of the life of a cell, as is best shown in the evolution of the male germ-cells.

On the other hand, it has been repeatedly established by various observers that Benda's "mitochondria" were not previously unknown elements of the cell, but that they have already been noted in many tissues and had been described under various names. For instance,

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undoubtedly some of Flemming's *fila*, some of van Beneden's microsomes, von la Valette St. George's cytomicrosomes and "Nebenkern," and most of Altmann's bioblasts, are identical with chondriosomes. The value of the recognition of this fact should not be underestimated, inasmuch as it has brought about a satisfactory simplification. From the same point of view another desirable result is the conciliation between two long-discussed and ardently supported theories of the structure of the protoplasm, namely, Flemming's filar and Altmann's granular theories; for it has been demonstrated that in many cases both have described the same substance and that this substance may appear in granular as well as in filamentous form.

As happens in every new field, the research work on chondriosomes has passed through a phase which may be properly characterized as the descriptive stage, the stage of pioneering work. At present the tendency is rapidly developing to attack the problem from the experimental side, and in this connection should be emphasized the value of the tissue-culture method by means of which many former observations have also been confirmed. The experimental methods, chemical research included, should prove very valuable, and should help to solve important problems, for although the importance of the chondriosomes is generally admitted, their rôle in connection with the differentiation and the life of the cell is much discussed. Finally, it should be pointed out that in the domain of pathology the cell protoplasm has hardly been explored in a systematic way and that, for instance, the study of the cytoplasm in tumors might perhaps give results not only interesting but also of some practical value.

Mrs. Margaret R. Lewis and Dr. R. B. Robertson have applied the method of tissue cultures and vital staining to the study of the mitochondria in the germ-cells of a grasshopper (*Chortippus curtipennis* Scudd.) and their results are in agreement with the conclusions drawn by others from the study of teased tissues or of fixed and stained preparations. Mitochondria are found in the primary spermatogonia of *Chortippus* as small, delicate granules. They certainly do not arise in the male germ-cell, since they are already present in the earliest germ-cell, and there is no evidence that they are formed at the expense of any nuclear material. In the prophases of the first division the mitochondria dispose themselves in threads and surround the spindle. This substance is divided into two clumps of about equal size during both spermatocyte divisions. In the spermatid the mitochondria conglomerate into a compact body, the previously so-called "Nebenkern," which divides into two parts and, after undergoing several changes in the structure, finally builds two threads which surround the axial filament extending along the length of the middle piece of the spermatozoon.. Besides the mitochondria, these authors found, in all generations of germ-cells, granules that stain vitally with neutral red.

These granules exhibit no definite behavior and disappear during spermiogenesis.

Dr. Paul G. Shipley describes in *Trypanasoma lewisii* granules scattered through the cytoplasm which are more numerous at the anterior end of the organism and show a marked tendency to clump together at one or both ends of the nucleus. These granules are stained *in vivo* with Janus-green, are dissolved by acetic acid, and in permanent preparations (fixed and stained by the methods of Benda, Bensley, Meves, and Altmann) give characteristic mitochondrial staining reactions. It is therefore highly probable that these granules are mitochondria. Dr. Shipley found, furthermore, that the reactions of the kineto-nucleus towards mitochondrial stains, both in fixed and in vitally stained preparations, are very similar to those of the mitochondria, their behavior being analogous to that of the centrioles in other cells.

In the pancreas of the toad Mr. J. Albert Key has tried to elucidate the relations of mitochondria to zymogen-granules, which some authors believe to be very close. He injected the animals with pancreatic secretion or pilocarpin and fixed the pancreas at various periods after injection. He found on the filaments the spindle-like swellings that have been interpreted as the first appearance of zymogen granules. These swellings, however, do not stain with neutral gentian, neutral safranin, or neutral red, nor are they fixed satisfactorily in Zenker formalin material. On combining Bensley's neutral-gentian and acid-fuchsin methods, which differentiates mitochondria from zymogen granules, Key was unable to detect any difference between the swellings and the rest of the filaments. He states further that there is an absence of reciprocal changes in the number of mitochondria with variations in the content of zymogen granules found by others in other material; and he is led to believe that the zymogen granules are not formed directly from the mitochondria.

The purpose of the investigation conducted by Miss Madge DeG. Thurlow was to determine whether the number of mitochondria could be used as a basis for classifying nerve-cells into motor and sensory groups. Although her results were negative, the investigation leads to the interesting conclusion regarding the proportional number of mitochondria in cells belonging to the different nuclei of origin of the cranial nerves in the white mouse, the number of mitochondria present in each cell being determined by careful countings and measurements. The cells of the mesenphalic nucleus of the fifth, the cochlear and vestibular nuclei of the eighth, the nuclei of the sixth and seventh nerves, seem to represent extremes in the number of mitochondria. The largest number was found in the cells of the mesencephalic nucleus of the fifth, the smallest in the cells of the nucleus of the seventh. Large numbers of mitochondria were found also in the cells of the

cochlear nucleus of the eighth and of the nucleus of the sixth cranial nerve, whereas the cells of the vestibular nucleus of the eighth contain much fewer. The quantitative variations of mitochondria in the individual cells of one given nucleus are very slight.

Pursuing his researches on the behavior of the azo dyes in the body, Professor Herbert M. Evans has studied the ovary, and especially the atresic follicle, in their reaction towards the vital stains of the azo group. He finds that the beginning of the degeneration of the granulosa cells is often marked by an abrupt change in their reaction toward these dyes. Normally resistant to the entry of the dye, the degenerating cells may house large "droplets" of vital color, so that the whole follicular epithelium is finally laden with it. This reaction, however, is to be separated sharply from the so-called "macrophage" reaction, inasmuch as the granulosa cells that behave in this way show chromatolysis and other degenerative changes, and are short-lived. True macrophages play an important part in follicular atresia, and they are electively stained by vital dyes of this class. The later stages of follicular atresia are consequently marked by the presence of numerous macrophages laden with the dye. The macrophages must be considered as utilizing the products of the disintegrating ovum towards which they are attracted, and which they invade by an active penetration of the zona pellucida.

Dr. Katherine J. Scott's researches on the connective-tissue cells of animals stained vitally with acid azo dyes have led her to the conclusion that under no conditions are the mitochondria of connective-tissue cells vitally stained with these dyes. The dye granules undergo definite changes in accordance with the functional state of the cell, and so do the mitochondria; but the respective identities of dye granules and of mitochondria are always maintained.

Starting from the relations which are known to exist between the composition and concentration of the sea-water and the composition and concentration of the plasma, Mrs. Margaret R. Lewis studied sea-water as a medium for tissue culture. She finds that an excellent medium can be made with 90 parts of sea-water (diluted to make it isotonic with the plasma of the animal from which the cultures are to be made) + 10 parts of bouillon made from the muscles of the same animal. It has been found that about 10 (sometimes 15 and 20) parts of bouillon make the solution sufficiently hypotonic to offset any evaporation which may take place, and at the same time to furnish the necessary nitrogenous food for the tissue. To 100 c. c. of the above-mentioned medium are added 0.02 grams of $NaHCO_3$ to neutralize the acid formed by the culture and 0.25 grams of dextrose to supply the energy for growth of the tissue.

In vertebrates, as well as in invertebrates, several observers have quite recently described amitosis followed by division of the cell and

have considered this process as a normal way for cell multiplication. Dr. Macklin has devoted his attention to the fate of cells with elongated or constricted nuclei, and of mononucleated and multinucleated cells as observed in living cultures of embryonic chick tissue. He found that the constriction of the nucleus may end in amitosis and that repetition of the process may produce multinucleated cells. In no case has it been found that the parts became separated to form the nuclei of mononucleated cells. The only change which took place in these cells (some of them being observed for 12 hours continuously) occurred when they were undergoing mitosis. There was a disappearance of the nuclear membrane with a fusion of the karyoplasm of the two nuclear moieties and the formation of a single amphiaster. In this way there finally resulted two apparently normal nuclei contained within separate cells. These observations contradict the opinion gained through observation of fixed material, according to which cells may multiply by amitosis, and indicate that amitosis is a change in form of the nucleus rather than a method of cell proliferation.

Another contribution to the behavior of embryonic chick tissue in cultures has been made by Dr. Paul G. Shipley. A first group of cultures was made with tissue taken from the area opaca, before the formation of blood-islands and the elaboration of hemoglobin, and grown in the blood-plasma of an adult hen. In many cultures young erythrocytes were found which developed from undifferentiated, highly amœboid, very small, mononuclear elements. The process of erythrogenesis was initiated by a cessation of amœboid movement. The cell withdrew its processes and became round. The round hemoglobin-free cells still had the power of multiplication by mitosis, but usually hemoglobin was elaborated without further division, with the resulting formation of the hemoglobin-bearing erythrocytes. In this way a small number of normal red cells were produced in cultures, but most of the erythrocytes differed in many respects from the normal type, which under the condition existing in the cultures should not be surprising. Several cultures showed, after 24 to 30 hours, the development of the heart-muscle, which began to beat rhythmically. Regularity in beat was not maintained for over 24 hours; after this time the rate became slower and slower until it ceased; pulsation could, however, for a time be reinduced by mechanical or thermal stimulation. These facts show that the life of cells in cultures in not merely a series of "survival phenomena" on a down-grade of progressive differentiation.

Professor Eliot R. Clark studied the reaction of mesenchyme cells in the tadpole's tail toward injected oil-globules. His investigation was undertaken in order to find out the reaction of the mesenchyme cells to the pressure of globules of fluid artificially introduced into the tissue-spaces. The problem is interesting in its relations with the formation of lymphatic vessels. One view is that the lymphatics are

formed by the transformation of mesenchyme cells reacting towards an accumulation of fluid in tissue-spaces by flattening out and forming membranes around the inclosed lakelets. Such "blisters" are held to be the beginning of lymphatic endothelium, vessels being formed by the coalescence of neighboring blisters. Clark found, however, that the mesenchyme cells in the injected tadpole's tail did not show any tendency to flatten out and form membranes around the globules of oil, but they maintained their identity as branched mesenchyme cells, retaining their property of slow progressive movement. The only observable reaction on the part of living cells toward the injected globules was a more or less intense leucocytosis, caused probably by slight grades of infection. In several instances leucocytes were watched as they moved toward an oil-globule, and were seen to flatten out on its surface and then move away again. It would thus appear that the opinion that mesenchyme cells are stimulated by the mechanical pressure of globules of fluid to flatten out and form membranes, and that these membranes are the beginnings of the lymphatic endothelium, fails to stand the test of experiment and of direct observation on the living animal.

Doctors Paul G. Shipley and Robert S. Cunningham have studied the rôle of the omentum in absorption from the peritoneal cavity. To avoid as completely as possible all causes of error, they adopted the following technique. The omentum was drawn out of the body of the animal through a midline incision and immersed in the fluid to be studied. In a number of cases participation of the lymphatics in the absorption of the material was eliminated by preliminary ligature of the thoracic duct. The difficulty of keeping the animal under an anesthetic for several hours led the authors to use animals that had been decerebrated; for such an animal will lie motionless and rigid, and at the same time the pulse and respiration and the blood-pressure will remain fairly normal. The omentum of animals prepared in the manner described were immersed in true solutions, in pseudo-solutions of high molecular dyestuffs like trypan-blue, in colloidal metals, and in filtered India-ink. After exposure for varying lengths of time, the animals were killed and their tissues examined. The use of a solution of citrated cyanide, isotonic with the blood of the animal, followed by fixation of the tissues with acid formalin, enabled the authors to trace the route of removal of the original fluid, the citrated cyanide being precipitated in the tissues by the acid, forming Prussian blue. The results were most extraordinary and most unexpected: it was shown that the drainage was effected by the blood-vessels. The results were identical, whether the thoracic duct had been ligated or not, and experiments with other substances, namely, trypan-blue or India-ink, led to the same conclusions. Consequently it is probable that the omentum plays an important rôle in the drainage of the peritoneal

cavity, and the path by which absorbed substances leave the omentum is not a lymphatic but a hæmic one.

Dr. E. V. Cowdry has studied the so-called "chromophile cells," especially their canalicular apparatus and their mitochondria, in the brain of the white mouse. He has found that chromophilic cells occur under normal conditions in the brain of the white mouse and are distributed unequally in the different parts of the nervous system. They are most abundant in the cerebral cortex, and are progressively less numerous in the cerebellum, corpus striatum, thalamus, midbrain, and medulla. They are of very rare occurrence in the spinal cord, spinal ganglia, and sensory ganglia of the cranial nerves. Chromophilic cells, as seen in fixed and stained preparations, vary greatly in structure. There is usually more or less shrinkage of the cell-body and the nucleus may also be shrunken. The acidophilic and basophilic nuclei are particularly prominent, and the ground-substance of the nucleus stains intensely with both acid and basic dyes. There is an increase in the amount of Nissl substance, the Nissl bodies becoming confluent and forming a homogeneous mass. The cell is hyperchromatic and the canalicular apparatus is unaltered. The mitochondria either increase in number or stain intensely, or else lose their discrete outlines and form a homogeneous diffuse deposit which stains intensely by the mitochondrial methods of technique. This change in the mitochondria occurs in the cell-process in the neighborhood of the cell as well as in the cell-body. Although the nucleus may be completely obscured by this cloud of mitochondrial substance, it still remains and stains in the usual way with hematoxylin and eosin. The lability of the mitochondria and the constancy of the canalicular apparatus in the chromophilic cells confirm the author's view that these two structures are physiologically as well as morphologically distinct.

The same author has summarized in a general article our knowledge of the general functional significance of the mitochondria. He reviews in succession the data concerning their morphology, their relation to other cytoplasmic constituents, to metabolism, to histogenesis, to inheritance, and to the pathology of the cells; and gives for the first time an account of their chemical properties, including their behavior towards vital stains, of which he has made a special study. His conclusions are that a great deal of work still remains to be done before we can hope to understand the functional significance of these bodies.

HUMAN EMBRYOLOGY IN GENERAL.

Owing to our increasing efforts, the collection of human embryos has continued to grow rapidly. Twenty-five years ago it took 10 years to collect our first 100 specimens; 5 years to collect the second hundred; 3 years for the third hundred; 2 years for the fourth hundred. And now, since the collection has been taken over by the Carnegie Institu-

tion of Washington, 400 specimens have been collected each year. On an average, about 60 physicians have contributed each 100 specimens, and the whole collection has been obtained from 509 physicians residing in 46 States and countries. As might be expected, many of these physicians are connected with hospitals, and, as far as can be ascertained, 59 contributing hospitals are now upon our lists. The largest number of specimens came from Maryland, 899 coming from this State alone, most of them from Baltimore. We have received 174 specimens from New York, 59 from Michigan, 56 from Pennsylvania, 41 from the District of Columbia, 43 from Illinois, 37 from California, 35 from Ohio, 30 from Massachusetts, 27 from Connecticut, 26 from New Jersey, 22 each from Wisconsin and Maine, 21 from South Carolina, and 27 from the Philippines. The remaining specimens, less than 20 for each State, came from 31 States and countries. In the collection there are 23 Filipino embryos, 6 Chinese, 4 Japanese, 3 American Indian, 1 Korean, and 86 embryos known to be from the American negro.

The Johns Hopkins Hospital contributed 99 specimens, and these came mostly from the gynecological and obstetrical clinics. Nine other hospitals in Baltimore sent specimens, 27 coming from the Hebrew Hospital and 16 from the Church Home and Infirmary. Eleven hospitals in New York contributed: Bellevue 35, Kings County 27, and the Lying-In Hospital 18 specimens. A complete statement regarding the collection is now being prepared for the press.

I wish to emphasize again the importance of this cooperative research undertaking, in which, on account of their altruisitic spirit, over 500 persons, most of them unknown to us personally, have taken part. Without their contributions our work would be impossible. The best specimens are sent to us from hospitals. From among them it has been possible to obtain several rare ones *in utero*, the organ having been removed for various reasons. Our colleagues in Baltimore have been especially considerate in sending these prizes directly to our laboratory, and sometimes they have arrived with the embryo still living.

There are 141 publications which are based in part or entirely upon this collection. Most of them are by members of our staff, but a fairly large number are by colleagues in other institutions, who have come here to study the collection or to whom we have loaned individual specimens. In a few instances rare specimens in other collections have been brought here to be compared with our embryos and to be worked up for publication.

In the past year several general studies have been published, for which this collection has been utilized as a basis. They are as follows: A general discussion on the development of the fetus by Professor Warren H. Lewis, one on the development of the heart by myself, and one on the development of the digestive tract by Professor William

S. Miller, of Madison. Professor George B. Jenkins, of Louisville, has used the collection in a study of the development of the olive, and Professor Kingsbury, of Ithaca, in a study on the development of the human pharynx. Dr. Oswald S. Lowsley employed a few of our specimens in the preparation of his paper on the prostate gland in old age, and lastly Professor Thomas S. Cullen has based almost entirely upon our embryos his study of the development of the umbilical region, which is given in the first chapter of his treatise on this subject published recently.

Biometric studies on the human embryo by Dr. Michael Reicher, to which reference was made in Year Books Nos. 12 and 13, were interrupted on account of the European war. It is planned to continue this work in the near future, as our specimens are increasing rapidly in number and it is desirable to obtain a satisfactory antenatal curve of growth. Through cooperation with the obstetrical department of the Johns Hopkins Hospital two studies upon this subject have been prepared by Professor A. W. Meyer, of Leland Stanford Junior University, one on the curves of prenatal growth and autocatalysis, and the other on fields, graphs, and other data of fetal growth. These have been published as Contributions to Embryology, No. 4 (Publication No. 222) by the Carnegie Institution of Washington.

In this connection I may mention my own publication on the age of embryos and the duration of pregnancy; also my paper on anatomical characters of the human brain, which are believed to vary according to race and sex. The latter forms one of the essays in a collection of papers of especial use in the study of Afro-American problems. It should be extended to include the fetal brain. In order to gather more material a circular entitled "On the study of racial embryology" was widely distributed in Asia and in British North America; and the result of this effort has been the addition of a number of valuable specimens of the embryos of different races. Studies of this kind call for the cooperation of many individuals as well as for joint investigations by the embryologist and the physical anthropologist. To develop this plan I have repeatedly sought the advice of Professor Schlaginhaufen, who has been most generous in giving it. I also want to add that many missionaries and physicians in foreign countries have shown the greatest willingness in sending specimens for our collection.

The fifth contribution to the study of the pathology of human embryos (by myself) appears in Publication No. 224 of the Carnegie Institution of Washington. It is entitled "The human magma réticulé in normal and in pathological development." In this study it is shown that fibrils forming the reticular magma are always in direct continuity with those of the mesenchyme of the chorionic wall. This fact can be easily demonstrated by means of the Van Gieson stain, and reticular magma must therefore be viewed as embryonic connective

tissue extending into the cavity of the ovum. The stronger strands of magma are accompanied more or less by mesenchyme nuclei, showing that the magma itself must be viewed as an independent connective tissue identical with the mesenchyme of the chorion. As the amnion extends, these strands are pushed aside and their final remnants are seen in that portion of the exocœlom which encircles the umbilical cord.

In pathological specimens the reticular magma increases in quantity in the earlier stages of development, the increase continuing for a number of months of pregnancy. Frequently the meshes between the reticular fibrils are filled with peculiar stratified granules which take on an intensive hematoxylin stain. Often the amnion is destroyed early in development, and in this case the magma may dissolve; but sometimes it increases greatly in quantity, forming a gelatinous mass. Frequently, pathological ova are encountered in which the development of the embryo is retarded, and the amnion is often found filled with a flaky deposit that, as time goes on, increases greatly in quantity and finally forms large crusts which invest the embryo. In other cases there is a marked hydramnois, and in certain instances, in which the amnion is destroyed, the magma dissolves, leaving only the embryo floating in the fluid encircled by the chorionic wall. Specimens are also found in which the cavity of the amnion is greatly enlarged and is filled with a jelly-like substance, which in later stages may form crusts encircling the embryo. The true relation between the pathological changes of the contents of the exocœlom and of the cavity of the amnion remains to be determined.

Professor Florence R. Sabin has continued her work upon angiogenesis in the chick and the pig. The first vein of the embryo is the duct of Cuvier, which forms a direct connection between the aorta and the vitelline veins. The cardinal system in general arises as a longitudinal system of veins from primary branches of the aorta. The cardinal system proper extends throughout the zone of the myotomes and lies in the Wolffian groove ventral to the myotomes. In the chick the direct connection between the aorta and the heart occupies the zone of the first three or four myotomes. Eventually the plexus of the vessels representing the duct of Cuvier in the chick covers the zone of the first seven myotomes. In the pig the posterior cardinal vein develops from lateral branches at the same time as the nephritic tubules, and these lateral branches alternate with the nephritic tubules. In the chick the posterior cardinal vein develops more rapidly than the tubules, and comes in part from lateral branches of the aorta, which are intersegmental, but mainly from dorsal segmental branches, which, however, do not grow first to the spinal cord, but rather directly lateralward to the Wolffian groove, where they anastomose to make a longitudinal vein.

The work of Dr. Robert S. Cunningham on the development of the lymphatics of the lung is now concluded and forms Contribution No. 12 in Publication No. 224. Dr. Cunningham concludes that the development of the lymphatics within the lung depends upon the division of the vessels into two groups—those associated with the veins and connective-tissue septa, and those associated with the arteries and the bronchi. The former grow very rapidly, and, following each of the branches of the pulmonary vein, pass to the pleura. There are at first only two or three lymphatics with each vein. In the early stages the terminal veins lie about midway between the adjacent bronchi, and in this plane a sheet of lymphatics develops from the vessels surrounding the veins and passes to the pleura, where they mark out the boundaries of the distribution of each bronchus. These vessels anastomose with those that grow direct to the pleura from the plexus on the trachea. The bronchial vessels develop more slowly, and at first are to be found only around the larger bronchi. As these structures increase in size and number, the lymphatics surrounding the main bronchi send vessels to the smaller ones, and these form a plexus around each of the bronchi, so that the bronchial tree is surrounded by a continuous series of branching tubes made up of lymphatic vessels. From every point of division of the bronchi, lymphatic vessels pass to those of the veins. Those around the terminal bronchus leave it near its ending in the atria, and pass to join the lymphatics of the veins or septa, or, more rarely, those of the pleura.

Lymphatics also arise from the retroperitoneal sac and grow upward behind the diaphragm to enter the lower pole of the lower lobe of the lung. These vessels form a plexus on the median surface of the lower lobe, and send branches to the pleura of the other surfaces and into the lung along the veins. Plexuses develop here, as is the case with those that come from above, and the two groups soon anastomose. In the adult there are lymphatic vessels accompanying the bronchi, the arteries, and the veins; these anastomose freely. There are also vessels in the connective-tissue septa which drain chiefly into those around the veins, and, to some extent, into those of the bronchi and arteries, near the point where the vein and the bronchus separate to take their relative positions in relation to the lobule. There are numerous anastomoses between the deep vessels and those of the pleura, but probably most of the flow is toward the hilum. All the deep vessels, together with the greater number of the pleural vessels, drain into the nodes at the hilum; but the vessels of the lower half of the pleura of the lower lobe drain through several vessels to the preaortic nodes. These vessels pass through the ligament of the lower lobe and behind the diaphragm.

The work of Mrs. Eleanor Linton Clark, which was alluded to in previous reports, is now nearing completion. Her last publication is upon the lymph-flow in the early superficial lymphatics in the living

chick. Her findings, briefly stated, are as follows: The primary superficial lymphatics of chick embryos form a rapidly growing, frequently anastomosing, capillary network. This primitive plexus maintains numerous open connections with the venous system in certain places. For over 24 hours the pressure in these earliest lymphatics remains less than the side-pressure in the connecting veins and, consequently, there is no lymph-flow in the early plexus. Instead, it contains blood, which backs up into it from the communicating veins. The pressure of the fluid in the lymphatics gradually increases and finally overcomes that of the veins. The first lymph-flow which is then established is feeble and easily disturbed. The lymph-flow gradually becomes more rapid and steady, but its course is readily altered by various mechanical factors. A day later the pressure in the superficial lymphatics has increased still more and, for various reasons, the outflow into the veins is interfered with. At certain points two conflicting pressures are present, and here the lymph-flow becomes sluggish. The endothelium of these early lymphatics responds to the passage of fluid over its interior by the differentiation of definite ducts or channels out of the indifferent primitive network. With the increased flow of lymph these channels enlarge and others are formed. That the formation of such channels is due to the lymph-flow and to mechanical factors, rather than to arbitrary predetermination, is evident from the frequent variations which occur in the position of the main ducts in chicks of the same stage. The endothelial wall of the early lymphatics also responds to the increased pressure, caused by interference with the lymph-flow and the damming back of fluid, by expanding to form sac-like enlargements. The size which these sacs may attain is influenced to some extent by the looseness of the surrounding tissue.

Professor Franz Keibel, our Research Associate, has made a new report upon early implantation. To determine the line of demarcation between maternal and embryonal structures he employed Bielschowsky's method, with which the connective-tissue fibrils are stained intensely black, so that (as they are numerous in the mucous membrane of the uterus) it is quite easy to separate the two kinds of structures. In a specimen about 3 weeks old it is found that the individual trophoblast cells are in advance in implantation and where they come in contact with the connective-tissue fibrils the latter swell and disintegrate. At this stage of development the trophoblast cells do not intermingle with the decidua cells. The epithelial cells of the glands and the endothelial cells lining the blood-vessels degenerate and disappear in front of the advancing trophoblast. The line of separation is well-marked by the presence of connective tissue on the maternal side and by its absence on the embryonal side. From this study it would appear that the syncytium prevents the maternal blood from coagulat-

ing and takes up and digests pabulum (embryotrophe) as well as nutritive substances from the mother's blood. Hence the villi of the chorion show an analogy to those of the intestine. The function of destruction and absorption of maternal tissues is not to be ascribed to the syncytium and giant cells alone, but also to the cells of the trophoblast, for these wander out and come in contact with the maternal cells and no doubt are responsible for their solution. The syncytial giant cells, however, are often found far out in the tissues of the uterus as well as within the maternal blood-vessels. In the latter case they do not destroy the maternal cells, but in Professor Keibel's opinion they themselves are fated to destruction.

NEUROLOGY.

Studies on the development of the arachnoid spaces and brain membranes and others on the establishment and character of the circulation of the cerebro-spinal fluid in mammalian embryos, have been published in two shorter papers by Dr. Lewis H. Weed. A larger and more comprehensive account of the whole work has been given by him in the Contributions to Embryology, vol. v (Carnegie Inst. Wash. Pub. No. 225). He devised a method of replacing the cerebro-spinal fluid in living pig embryos with an isotonic solution of potassium ferrocyanide and iron-ammonium citrate. After the embryos had been kept alive in an incubator for varying periods, they were fixed in a fluid containing dilute hydrochloric acid. This resulted in the formation of Prussian blue as a granular deposit in all the spaces that had been invaded by the injected solution. By the use of this method the cerebro-spinal fluid was replaced by a true solution, without any increase in pressure and without any toxic effect upon the embryos. It was thus possible to obtain trustworthy evidence regarding the distribution and spread of the cerebro-spinal fluid.

Dr. Weed finds that the first extra-ventricular spread of the cerebro-spinal fluid occurs in embryos over 14 mm., long, and that this is approximately coincident with the development of the tufts in the chorioid plexuses of the fourth ventricle. The spread occurs through a differentiated oval area in the superior central portion of the roof of the fourth ventricle. This area can be recognized histologically before it begins to allow the passage of fluid. In 18 mm. pig embryos, the extra-ventricular spread is by no means extensive; but two areas of escape for the ventricular fluid exist in the two divisions of the rhombencephalic roof. The superior of these points of fluid-passage is the one also concerned in the primary outflow of the fluid, whereas the inferior is a somewhat similar area of ependymal differentiation in the caudal half. After this stage is passed, the further extra-ventricular extension of the fluid occurs rapidly. The peribulbar spaces are first filled with the fluid, and from this region a spread downward in the

perispinal spaces occurs. Simultaneously with this caudal enlargement of the fluid-spaces the fluid may be traced along the ventral surface of the mesencephalon. In pig embryos of 23 mm. these replacements show a total filling of the ventricular system with the blue and an almost complete surrounding portion of the cerebro-spinal axis with the granules. The superior portion of the mesencephalon and the cerebral hemispheres are the last parts of the nervous system to show evidence of a pericerebral investment. This final establishment of the adult cerebro-spinal relationship occurs in pig embryos of about 26 mm.

The rapidity of the spread of the fluid in embryos between 18 and 23 mm. is apparently due to the marked acceleration in the rate of production of the ventricular cerebro-spinal fluid, which is coincident with the formation of the chorioid plexuses of the third and fourth ventricles. As soon as these tufts develop, the fluid is produced in amounts that far exceed the quantities for which the more slowly enlarging ventricles can provide.

At no time was there evidence of the passage of cerebro-spinal fluid from the ventricular system into the pericerebral and perispinal space through any place except the two localized areas in the two portions of the rhombic roof. These two opendymal areas both represent intact membranes, and are apparently differentiated for the passage outward of the ventricular fluid. Both are differentiated at a slightly earlier stage than that at which they function actively. In the smaller embryos the superior area membranacea fulfills by far the more prominent funtion, but after the establishment of the lower point of fluid-passage it undergoes regressive changes. The area membranacea inferior continues to develop and function actively. It gradually forms, with increasing growth of the embryo, a caudal projection beneath the cerebellum. This inferior area in the roof gradually occupies with its differentiated ependyma the whole velum chorioideum inferius, and remains as a functional membrane during early fetal life and possibly throughout the adult existence.

Along with the investigation of the spread of the cerebro-spinal fluid, a study was made of the character of the tissues through which the spread occurred, and a full description of the development of the cerebro-spinal spaces in the pig and in man is given in Dr. Weed's papers. He describes the subarachnoid spaces as developing out of the periaxial mesenchyme. This process involves the transformation of the small "tissue-spaces" of the mesenchyme into larger subarachnoid channels.

The first signs of the differentiation are seen in the basal portion of the skull, in the region around the medulla oblongata, and consists of a gradual increase in the size of the mesh. At first the process appears as a mere spreading apart of the cell-bodies on the introduction

of more fluid into the so-called tissue-spaces. After the length of 18 mm. is passed—at which stage a great augmentation in the extra-ventricular spread of the cerebro-spinal fluid occurs—the phenomenon of the disruption of the mesenchymal strands in the peribulbar tissues may be made out. Many of these strands may be observed to have been broken off, sacrificed to a few larger persisting trabeculæ. The cells that give rise to these disrupted strands appear to recede, until one of the larger surviving elements is reached, when they adhere and apparently aid in the future production of a permanent arachnoidal trabecula. But associated with this breaking-down of the mesenchymal mesh, and with this formation of a smaller number of persisting strands, there occurs another phenomenon of great importance. The larger meshes formed by the process appear to be filled with a fluid much richer in protein than that contained in the original (much smaller) interstices. This fact is proved by the great quantity of the albuminous coagulum found, on histological examination, in all of the enlarged spaces in the tissue. The occurrence of this large amount of albuminous coagulum is apparently related directly to the distribution throughout this tissue of the embryonic cerebro-spinal fluid; for this embryonic fluid is very rich in protein material, as can be seen by the partial filling of the embryonic cerebral ventricles with the clotted albumin. In this respect the embryonic fluid differs markedly from that of the adult, in which the protein-content is suprisingly low.

While these spaces are in process of formation the cell-bodies of the disrupted mesenchymal elements adhere to the persisting arachnoidal trabeculæ and gradually become transformed into the typical cuboidal mesothelium of the subarachnoid spaces. The very useful term "arachnoid membrane" is introduced to designate the outer intact membrane of the arachnoidea as distinguished from the arachnoid trabeculæ. This portion of the arachnoidea first appears as a distinct line of mesenchymal condensation separating the mesenchyme into the primitive arachnoid and dura mater. This rather thin zone of cellular density in reality represents not only the outer surface of the arachnoidea, but also the inner surface of the dura mater. At first these develop in close fusion, but as the length of 50 mm. is attained in fetal pigs, a separation of the two membranes over the cerebral hemispheres becomes possible. At this stage also a mesothelial polygonal cell-pattern may be made out on the inner surface of the dura by means of silver-nitrate reductions. With this cleavage of the two surfaces, the arachnoid membrane is rapidly differentiated, forming an intact layer over the subarachnoid spaces. The cells covering the surface membrane seem to change gradually into cells of cuboidal type, similar to those covering the arachnoidal trabeculæ.

During the year three papers have been published that deal with the embryology of the internal ear. Two of these are on the endolymphatic

appendage, and one is on the development of the tissue-spaces surrounding the membranous labyrinth.

The development of the endolymphatic appendage in the turtle (*Chrysemys marginata*) has been described by Professor Keibel. His observations refer particularly to the relation existing between the appendage and the area at which the ear-vesicle finally becomes detached from the skin. This problem involves the homology of this appendage as it is found in the different vertebrates, and concerning which there has been active discussion during the past few years. Professor Keibel maintains that the place at which the ear-vesicle detaches itself from the skin has a direct bearing on the question of the homology of the ductus endolymphaticus—a view contrary to that generally expressed by other recent writers. He finds the ductus endolymphaticus to be an homologous structure in amphibians, reptiles, birds, and mammals, although it is not always a morphological equivalent. In these forms (such as *Anura* and *Ascalabota* in which certain portions of the endolymphatic appendage undergo special development) such parts early make their appearance as projecting pouches peripheral to the point of separation from the skin. These parts have no homologues in selachians, but already exist in them in an indifferent condition, as a portion of the ductus endolymphaticus.

Some interesting features in the development and topography of the endolymphatic appendage in the human embryo have been published by Professor George L. Streeter. An important capillary plexus is associated with the appendage, the character and communications of which are described by Dr. Streeter for the first time. He finds that throughout the greater part of fetal life the endolymphatic appendage is ensheathed in a vascular plexus, the plexus endolymphaticus, which anastomoses on the one hand with the vessels of the rest of the labyrinth, and on the other with the transverse sinus, into which it drains through several openings. This plexus makes its appearance at about the time of the differentiation of the appendage into its adult subdivisions of duct and sac. It can be plainly recognized in embryos 30 mm. long. In embryos 50 mm. long it is well-developed and at that time forms a closely-meshed web completely investing the appendage, whereby the latter is virtually inclosed in a sheet of blood, from which it is separated only by the endothelium of the blood-spaces. In the course of its further enlargement and development in embryos 100 mm. long and over, the endolymphatic plexus becomes resolved into a few principal channels, connected with which there remain parts of the original plexus. The plexus persists notably in the neighborhood of the endolymphatic sac. One of the most constant channels developed through the endolymphatic plexus is the one forming the so-called vena aquæductus vestibuli. This forms along the side of the endolymphatic duct and the posterior margin of the endolymphatic sac and constitutes a direct communication between the vascular plexus sur-

rounding the labyrinth on the one hand and the transverse sinus on the other. It may be a single or a multiple channel. Through it are drained the plexus of the endolymphatic sac and some of the dural veins of the immediate neighborhood.

A communication concerning the development of the tissue-spaces around the membranous labyrinth has been published by Dr. Streeter. The largest of these are the scala vestibuli and the scala tympani. Their development was traced in human embryos from the earliest stage up to the adult type. The important fact was established that in their formation they follow a definite morphological plan. They spread from two foci, the larger one beginning as a rounded sac lying opposite the foot-plate of the stapes and lateral to the sacculus, from which point it subsequently spreads upward over the utricle and also downward along the apical side of the cochlear duct to form the scala vestibuli. The other focus is near the fenestra cochleæ, whence it spreads along the basal side of the cochlear duct to form the scala tympani. These foci can be definitely outlined in fetuses 50 mm. long. In 85 mm. fetuses the two scalæ extend spirally downward along the cochlear duct to a point three-fourths of its last turn from the tips of the duct; they do not communicate with each other. In fetuses of 130 mm. they extend to the tip of the cochlear duct and open into each other, thereby forming the helicotrema.

Although the spaces around the membranous labyrinth resemble in their histogenesis the formation of the subarachnoid spaces, they can not be regarded as an extension of these, because their development is *in loco* and independent of them. In the latest stage examined (130 mm. crown-rump length) the communication with the subarachnoid spaces has not yet been established.

Several papers have been published during the year on the anatomy and development of the nervous system. They include a morphological study of the inferior olivary nucleus in the human fetus; the vestibular and optic mechanisms and their relation to the falling reflex of cats; a clinical study of the Gasserian ganglion; and a study of the development of the pharyngeal pouches in the turtle, in which special attention is devoted to the neural placodes.

Professor George B. Jenkins has contributed a study on the anatomy of the inferior olivary nucleus of the brain, which forms a continuation of the studies on this subject previously published from this laboratory. Dr. Jenkins has approached the subject from the embryological side, and gives a morphological description based on reconstructions of the olive and its accessory nuclei in a human fetus, 280 mm. crown-rump length. His study also takes into consideration other fetuses belonging to the Carnegie Collection, in which the olive was studied but not reconstructed.

Doctors H. R. Muller and Lewis H. Weed have published an experimental study on the rotational reflex by which cats are able to turn

in the air while falling and to land squarely on their feet, together with a correlation of the anatomical factors concerned with this reflex. These investigators find that either the vestibular apparatus or the optic system is able to give rise to impulses during falling that result in rotation of the cat in the air; and they conclude that both of these mechanisms are normally employed during such a fall. If either the vestibular apparatus or the optic system is experimentally eliminated, the lack does not interfere with the reflex; but if both are deprived of function, the reflex does not take place. Regarding the anatomy of the efferent pathways concerned in this reflex, it was established that either the complete removal of the cerebrum or the removal of the whole cerebral cortex abolishes the reflex. Ablation of both motor areas, however, does not interfere with the reflex, a finding which indicates that the cortico-spinal tract does not participate in the mechanism.

A paper on the Gasserian ganglion has been published by Dr. C. M. Byrnes, in which he reports certain features of the topography of the ganglion, and describes an instrument which enables him to reach the foramen ovale with greater accuracy and safety. It also reduces the degree of visualization necessary in making injections into the ganglion in the treatment of trigeminal neuralgia. He describes the changes that occur in the nerve-trunks and the ganglion as a result of alcohol injections.

An investigation by von Alten on the development of the pharyngeal pouches in *Chrysemys marginata* has been published. It is a descriptive study including four embryonic stages—5 somites, 14 somites, 18–19 somites, and 22–23 somites, respectively. The author's intention was that this should be preliminary to a study on the histogenesis of the thymus. This plan unfortunately could not be carried out. At the outbreak of the European war he joined the army, but suffered a return of a previous sickness and died on April 3, 1915. His work has been published by Professor Keibel.

The study of the anatomy of human embryos has been facilitated in this laboratory by the development during the past few years of new technical procedures, which enable us to reconstruct mechanically the different parts of the embryo with much greater accuracy than had previously been possible. An account of these improvements has been published by Professor Lewis, by whom they have, for the greater part, been devised. His paper gives the technique now used in photographing sections, establishing guide-planes for reconstruction by means of the external form, and the preparation of wax molds, in which are made permanent plaster-of-paris casts of any of the parts desired. It is the permanency and accuracy of these casts that constitute their superiority over the ordinary wax-plate reconstructions. Dr. Lewis includes in his paper many technical points and formulæ that are of value in photographic and wax-plate procedures.

DEPARTMENT OF EXPERIMENTAL EVOLUTION. *

C. B. Davenport, Director.

Among the principal advances of the year have been: (1) the origin from a line of parthenogenetic entomostraca of a strain that produces both sexes, in the same individual, in varying proportions; and the analysis of this condition; (2) the demonstration that, so far as studied, similar factors occupy similar chromosomes and have similar intra-chromosomal relations in various different species of *Drosophila*, affording additional evidence of the fundamental nature of the structural mosaic of the germ-plasm; (3) the unraveling of the germinal factors present in the yellow daisy (*Rudbeckia hirta*) and the study of the numerous mutations that are arising in our strains; (4) the demonstration that the blood-plasma of fowls differs in the two sexes in fat and phosphorus content in the same way that pigeon eggs of prospectively different sex differ; (5) the demonstration of the inferiority, in solving the problems of the multiple-choice apparatus, of the offspring of alcoholic as contrasted with non-alcoholic parents; (6) the demonstration of dominant shortening factors in the genetic control of human stature; (7) the completion of the second volume of the unpublished scientific work of Professor Whitman.

STAFF.

The work of this Department during the present year has been carried on by seven resident investigators and various associates and assistants. Staff meetings have been held weekly, at each of which a member of the staff reported on his own work. In addition to his other duties the Director has continued his analysis of the data of human inheritance, especially stature and the elements of success in achievement. In this he has been assisted by Miss Mary T. Scudder. Dr. J. A. Harris and his assistants have made an investigation of selective death-rate that has required the raising of 600,000 seedling beans. He has also spent some weeks in the Everglades region of southern Florida and in the neighborhood of the Desert Laboratory, southern Arizona, studying the physico-chemical properties of vegetable saps in their relation to environmental factors. Dr. A. M. Banta has continued the cave experiments, but has put most of his time on the work of selecting daphnids for sensitiveness to light, continuing parthenogenetic strains, attempting to control sex, and breeding sex intergrades. Dr. Riddle has continued his editorial work on the Whitman manuscripts and data and his studies on the control of sex in pigeons. Dr. E. C. MacDowell has carried on investigations into the modifiability of the germ-plasm and the effects of "selection" in the

*Situated at Cold Spring Harbor, Long Island, New York.

modification of a Mendelian unit. Dr. Metz has made progress in his study of the evolution of the chromosome groups in flies and in the comparative factorial structures of chromosomes of related species. Dr. Blakeslee is making genetical studies on a wide range of flowering plants.

REPORTS ON INVESTIGATIONS.

THE GERM-PLASM AND ITS MODIFICATION.

COMPARATIVE STUDY OF THE CHROMOSOME GROUPS IN DIPTERA.

Dr. Metz reports as follows:

"The chromosomes of Diptera, unlike those of most animals, are normally arranged in symmetrical pairs, the two members of each pair remaining in close association with one another during the greater part of the life of the fly. Stages were studied all the way from the egg to the adult, and in each the same paired association was found. During maturation these pairs undergo a reduction division essentially like that in other insects (a fact previously described by Stevens), and the two members go into different germ-cells. It appears, then, that the egg and the sperm contribute equivalent sets of chromosomes, and that in the fertilized egg corresponding members of the two sets become associated in pairs and remain associated throughout the life of the new individual. This is made extremely probable by the fact that in many cases the chromosomes are of different sizes and shapes and may be individually identified. In all cases (save X and Y in the male) the two members of a pair are alike in size, form, and behavior. Indeed, in one species it is possible easily to distinguish each individual pair from every other, and to see that every chromosome associates with its corresponding mate. If the chromosomes are genetically continuous, as there is great reason to believe, then these facts leave no doubt that in the flies each chromosome from one parent pairs up and remains associated with its mate from the other parent.

"A careful study of these phenomena—especially the evidence from tetraploid groups, as given in the paper—lends considerable support to the hypothesis that pairing is the result of a constitutional (chemico-physical) similarity or likeness between corresponding members, *i. e.*, each chromosome seems to have a definite make-up, similar to that of its mate, but different from that of the others; hence it associates with its particular partner and with no other.

"Obviously these results lend material support to the theory that Mendelian factors are located in the chromosomes—a theory necessitating just such a definite qualitative structure and individuality as that which appears to exist in these flies.

"In connection with this investigation it became of considerable interest to learn the distribution of the phenomenon of chromosome pairing; and for this reason the study became much more comprehensive than it would otherwise have been. It involved about 80 species, from among the highest to the lowest families of Diptera. The chromosome behavior was found to be the same in all of them, leading to the conclusion that the paired association is characteristic of the order Diptera."

COMPARATIVE STUDY OF CHROMOSOMES THROUGH THE GENUS DROSOPHILA.

Dr. Metz has also undertaken a comparative study of the chromosomes in the genus *Drosophila*. In its entirety this study is a very

extensive one, which would require years for its completion, owing to the great number and wide geographic distribution of the species. As a contribution to this topic, Dr. Metz has sent to press a paper which includes descriptions of 12 distinct types of chromosome groups, distributed in about 30 species that have been studied.

GENETICAL STUDIES ON TWO SPECIES OF DROSOPHILA.

Dr. Metz has selected two species of *Drosophila* that have different chromosome groups from *D. ampelophila* for comparison of genetical behavior in the three. He has secured at least 16 mutations in these two species within the last 12 months. In the species (as yet unnamed) upon which most time has been spent 14 or more mutants have appeared and are now being studied, and some very significant facts have already appeared, even though some of the most interesting features still remain to be investigated.

"First and foremost appears the fact that some of the mutants in this species are almost exact replicas of some in *Drosophila ampelophila* (studied by Morgan, et al.), although the two species are in many ways very different. Not only this, but in so far as they have been studied these characters fall into similar groups on the basis of linkage. The most definite evidence of this kind is shown by the sex-linked characters (which have been studied more fully than the others). Two characters, "yellow" body-color and "forked" bristles, are, so far as their characteristics show, almost exact duplicates of the same (named) mutants in *ampelophila*, and a third character, "magenta" eye, may perhaps bear a similar relation to that called "garnet" in *ampelophila*. In both species these three characters are sex-linked. Furthermore, it seems probable from evidence now being obtained that they show similar linkage relations to one another in both cases. The evidence is not yet complete, but it suggests that the factors compose a similar linear series in each species. This, if it proves to be the case, can only be considered as indicating that these two species possess a similar germinal organization, and that the organization is a permanent feature; that is, a genetic continuity of germinal structure, in so far as the factors are concerned, will be shown to exist in the Drosophilas. If the sex-linked factors are located in the sex-chromosome (X-chromosome), as seems altogether probable, then this would mean that the sex-chromosomes in these flies are genetically continuous; that they must be transmitted essentially unchanged from one generation to another and from one species to another in the course of evolution.

"A brief review of these results has been published in *Science*, and a more detailed report is in press in *Genetics*.

"Further work with this new species and with the others I am studying offers a most promising field for further investigations. It remains to be seen whether the number of linkage groups in these will correspond to the chromosome number, as in *ampelophila*, and whether the euchromosomes can be related to those in *amelophila* as can the sex-chromosomes. Since the number and size relations of the chromosomes are different in each of the three species, some very interesting questions are involved. Likewise, it will be of importance to learn whether or not the two sexes differ in respect to "crossing-over" in my two species as they do in *ampelophila*, and whether this is correlated with observable cytological evidence. In fact, a wealth of promising lines

is now opened up and, what is most important, the study has already progressed far enough to make it reasonably sure that the results may actually be obtained."

EXPERIMENTAL MODIFICATION OF THE GERM-PLASM.

The attempt to induce changes in the germ-plasm of rats by means of alcohol vapor, described fully in the Year Book for 1915, page 130, has been continued by Dr. MacDowell. An abstract of his work to that date was published in *Science*, November 12, 1915, and is reprinted here:

"The purpose of this investigation is to compare the mental capabilities of rats whose parents were alcoholic with those of rats of normal parentage. It is commonly claimed that, in man, the children of alcoholics are less teachable than children of normals. However, the exceeding difficulty of obtaining genetically comparable controls in man makes the study of a lower animal, although vastly different psychologically, of great interest, since double first cousins—the closest relationship possible for such comparisons—can be used. The first criterion used for judging mental activity has been habit formation in a Watson puzzle-box. The habit to be learned consists of a trip to the rear of the box, breaking an electric circuit, and so opening the front door, and, returning to the front, entering the box for the reward of food. The data recorded consist in the times required to open and enter the door of the puzzle-box. Each rat has been given 225 trials; 145 rats have been employed in this training. The data, summarized in various ways, have been represented by graphs. Awaiting the results of a second set of training experiments of a different nature, which are being conducted as a check on the first method, no general conclusions are given and only provisional conclusions are drawn about the present work."

The following additional conclusions have been reached:

"First, it is clear that breathing the fumes of alcohol for 90 minutes a day for 100 days does not cause rats to produce young with any sort of physical abnormalities that can be observed. It has also been determined that, for judging the mental valuations, different tests may give opposite results, and the most closely related pairs of families may give opposite results, even when tested by the same method. In the light of these facts it immediately becomes apparent that no final answer to the main problem can be justified until the relative values of the different tests have been established and something is known of the range of variations in mental ability that may be normally inherited in white rats.

"In support of the above conclusions the following examples are cited: Experiment I includes a litter of rats from normal parents and one from alcoholized parents. The fathers were brothers, the mothers sisters, so that the offspring were double first cousins. Experiment II includes two corresponding litters, similarly related, from normal and alcoholized parents. Moreover, the fathers in this experiment were brothers to the mothers in experiment I. Therefore the relationship between the normal litters in experiments I and II was just as close as that between the two litters in each experiment; they were all double first cousins, all from the same grandparents.

"However, although the alcoholized parents in both experiments were similarly treated, and although the training of all the offspring was alike, in experiment I the training with the puzzle-box showed from every standpoint that the rats from the alcoholized parents were more successful than the rats

from normal parents, while in experiment II similar criteria indicated that the normals were more successful than those from alcoholic parents. Data are quoted in the following table to support this statement. There are five methods of comparison: (1) the average time per trial of all the trials; (2) the average time per trial for the last ten trials; (3) the average number of "perfect trials" (4 seconds or less); (4) the average number of "perfect days" (3 trials of 4 seconds or less); (5) the number of rats with three successive "perfect days."

Puzzle-box results for experiments I and II.

	Exp. No.	Male parents.		Female parents.		Result.
		Normal.	Alcoholic.	Normal.	Alcoholic.	
1. Averages per trial, all trials.	I	7.93	7.53	12.67	9.91	Alcoholics faster.
	II	13.04	15.69	23 80	12 91	Normal males faster.
2. Averages per trial, last 10 trials.	I	4.33	3.65	7.06	6.29	Alcoholics faster.
	II	4.10	6.43	4 64	7.47	Normals faster.
3. Average number of "perfect trials."	I	69.5	121 0	48.5	79.5	Alcoholics better.
	II	85.7	55 0	99 0	62.0	Normals better.
4. Average number of "perfect days."	I	6 0	16.4	0.75	9.5	Alcoholics better.
	II	7.0	2 0	9.0	0.5	Normals better.
5. Number of rats with 3 successive "perfect days."	I	1	4	0	1	Alcoholics better.
	II	3	0	1	0	Normals better.
6. Total number of rats used.	I	6	5	4	4	
	II	9	3	2	4	

"The multiple-choice apparatus has previously been described (Year Book for 1915, page 131). As explained, the method consists of teaching the rats to go for food to a door that bears a certain relationship to the other doors opened; and the correct door, in different trials, is always a different one. Now, this is obviously a more difficult proposition than learning to run behind the puzzle-box in order to open the door to the food chamber. Instead of basing the test on time the results of the multiple-choice training are based on the numbers of right and wrong doors that are chosen. For every trial the path taken by the rat is graphically recorded on a separate slip of paper, and the doors that are correctly or wrongly chosen are indicated thereon. This method was adopted partly to form a check on the results obtained from the puzzle-box; as such it has clearly demonstrated that the characteristics of a rat that make for the speedy solution of the puzzle-box problem are quite different from those called into play by the multiple-choice method. The same group of rats described as experiment I were trained on the multiple-choice apparatus. Three problems were presented, as well as a memory test, on the multiple-choice apparatus. In problem I the opened door farthest to the right was the correct one; in problem II the opened door farthest to the left was the correct one; in problem III the second opened door from the left was the correct one. The averages of the numbers of correct first choices and the averages of the numbers of wrong choices in these three problems are shown in the annexed table. There can be no question that the normal rats are superior, from the standpoint of this test, to those from alcoholic parents, thus reversing the results of the puzzle-box training.

"Since the two methods described have offered different results, the importance of a third method is manifest. Accordingly, to give further evidence on the relative abilities of the different rats, a circular maze of the Watson type has been built, equipped with a camera-lucida device for obtaining accurate

records of the paths taken by the rats. Two large-sized mirrors are suspended over the maze in such a way that the rays of light from the illuminated maze are twice reflected and passed through a lens in the top of a small camera-box. Inside this box the image of the maze is projected upon the record sheets. As a rat travels about in the maze its image is followed with a pencil on the record sheet, and in this way an accurate record of every trial is obtained. These lines are subsequently measured with a chartometer, so that the distances traveled may be calculated. The time per trial is also recorded. Although 29 rats have been tested on this maze, no statement of results can be made at present.

Multiple-choice apparatus—Rats in experiment I.

Problem.	Parents normal.		Parents alcoholic.		More successful group.
	Correct.	Wrong.	Correct.	Wrong.	
I	5.63	7.55	5.13	8.61	Normal.
II	4 40	12 62	3.56	16.14	Normal.
III	3.82	11 81	2.52	18.56	Normal.

"As the rats grew to be more than a year old, there appeared a very high incidence of tuberculosis, so that in many of the experiments the maze and memory test could not be made.

Summary of rat training, 1915–16.

Investigation.	Test No.	No. of rats.	No. of trials.
Puzzle box: Memory tests.	I	15	810
	II	15	828
	III	10	459
	V	8	423
Multiple choice: Problem 1.	I	17	8,500
	VI	8	2,240
	VIII	11	3,080
	IX	26	5,460
Problem 2	I	17	1,190
	VI	8	2,240
	VIII	11	3,080
	IX	26	5,460
Problem 3 . .	I	17	1,190
Memory:			
Problem 1. . . .	I	17	2,040
Problem 2. . .	I	17	4,420
	IX	13	1,820
Maze.	A	19	1,596
	IX	10	840

"As it became more and more evident that the alcohol taken in by the parents had not made any very striking modification in their children, plans were made to start a second group of experiments in which the amount of alcohol administered should be greatly increased. A start has been made on this work with 8 pairs of rats, which are being made dead drunk every day. There has been developed a much shortened and standardized system of train-

ing which will enable the rats to be fully tested before the age of the high incidence of tuberculosis.

"The table following gives some idea of the number of tests made in getting evidence as to the relative intelligence displayed by the offspring of alcoholized and of non-alcoholized rats."

Insufficient funds have prevented the continuance of the experiment on the modification of the germ-plasm by extremes of atmospheric conditions. Meantime the plant is being maintained in good condition for future use. Even though we may have doubts of getting positive results, still, in view of the assurances of other biologists that they have gained modifications by this means, it is eminently our work to make the trial.

THE SIGNIFICANCE AND CONTROL OF SEX.

SEX IN BIRDS.

To this Station seems to have fallen the opportunity of demonstrating that the current view that sex is determined solely by the sex-chromosome is too narrow. It is chiefly Riddle who is developing this field. A summary of his results were presented before the American Society of Naturalists at the Columbus meeting and has been recently published in the *American Naturalist* under the title: "Sex control and known correlations in pigeons." In this is set forth 10 lines of evidence that the inherent tendencies of the fertilized egg in respect to sex may be altered by other factors. Riddle's chemical studies on eggs destined to produce males or females, together with a review of the literature, have led him to the conclusion "that sex-control, in the several forms in which it has been accomplished, has been accomplished fundamentally by the same means in all—a changed metabolism, in which a higher water-content of germ and higher metabolism for male production, and lower water-content and decreased metabolism for female production have been definitely shown to be associated in a number of instances." He concludes:

"The studies that have thus far been made on sex, and on the experimental control of sex, in pigeons go very far, we believe, towards an adequate demonstration that germs prospectively of one sex have been forced to produce an adult of the opposite sex; that germs normally female-producing have, under experiment, been made to develop into males; and that germs which were prospectively male-producing have been made to form female adults. That neither selective fertilization, differential maturation, nor a selective elimination of ova in the ovary can account for the observed results. Further, and perhaps of more importance, these studies throw much new light on the nature of the difference between the germs of the two sexes. This difference seems to rest on modifiable metabolic levels of the germs; males arise from germs at the higher levels, females from the lower; and such basic sex-differences are quantitative rather than qualitative in kind."

Of special interest, as demonstrating the chemical basis of sex, is a paper published by Riddle and Lawrence, Sexual differences in the

fat and phosphorus content of the blood of fowls, (*American Journal of Physiology*, vol. 41, 430–437). They show that in adult male fowl, non-laying females, and females laying eggs the relative amounts of phosphorus are as 100:115:205, and the alcohol-soluble fractions (fat) are as 100:116:181, respectively.

"When one begins from the point of vantage of the demonstrated initial difference in storage metabolism (particularly of fat and lecithin) of male- and female-producing ova of the pigeon, it is clear that every new and subsidiary hypothesis are unnecessary for the general understanding of many hitherto puzzling sex phenomena. A higher fat-content of the blood of woman, female crab, and hen than of man, male crab, and cock is [my view] the expected result of a mere continuance or persistence of the observed relative powers of the eggs."

SEX INTERGRADES IN CRUSTACEA.

Dr. Banta has found that in the midst of a parthenogenetic series of *Daphnia*-like forms—a species of *Simocephalus*—there occurred a female which produced some normal males and also some of mixed or intergrading sex. The animals are transparent, so that the constituents of their sex-glands may be seen; in addition 8 secondary sex-characters are recognized. As for the 2 sex-glands, they may be of the same or of opposite sex. Even one and the same gland may produce sperm at one time, eggs at another, or sperm and eggs simultaneously. As for the 8 differentiating secondary sex-characters, they may be all such as belong to one sex, or 1, 2, 3, or 4 may belong to one sex and the remainder to the other. Most of the possible combinations of primary and secondary sex-characters are realized in the sex-intergrades studied; *e. g.*, female intergrade, normal except for one male secondary character; female intergrade, with several or all of its secondary sex-characters those of a male; hermaphrodites with various combinations of secondary sex-characters; male intergrades with several, though never as many as 8, female secondary sex-characters; male intergrades with a single female secondary sex character.

"The percentages of the various sexual types produced by different mothers varies greatly. In general there is some relation between the secondary sex-characters of the female intergrade and the sex array and the proportions of each type in her offspring. Female intergrades with few male characters tend, in general, to produce fewer males and male intergrades than female intergrades with several male characters. Some of the female intergrades with a large number of male secondary characters are almost sterile. Many others, including nearly all those with as many as 6 or 7 male secondary characters, are entirely sterile. None with 8 male secondary characters have been known to produce young. The sterile female intergrades produce eggs, but the eggs fail to complete their development in the brood-pouch, or, as in the most extreme female intergrades, the ovarian development of the eggs is not completed and the eggs disintegrate within the ovary.

"The testes in the male intergrades frequently do not contain large amounts of sperm. In such individuals the sperm-ducts are frequently lacking and the

testes shorter than normal. In the majority of the male intergrades some such abnormality exists in the reproductive system. These details are given to show how complete a series the sex intergrades really form.

"Sex here reveals itself not as a fixed and definite state, but as a purely relative thing. With this material no arbitrary classification into males and females is justifiable or possible, not only because of the confusing admixtures of male and female secondary characters, but also because the same individual, even the same sex-gland, may develop eggs and sperm at the same time or sperm at one time and eggs at another time.

"By selecting as mothers female intergrades with several male characters the production of sex intergrades has been continued for 19 generations. There has been no apparent reduction in vigor or change in the character of the offspring produced, and (contrary to my earlier expectations) it is now hoped that the material may be maintained as long as desired.

"Several normal females from the sex-intergrade stock produced only normal females, and from these only normal females were produced throughout succeeding generations. The origin of the sex-intergrade strain may be referred to as a mutation. The origin of all-female-producing strains from within this sex-intergrade stock is a return mutation. Several of these return mutations have been observed and probably others occurred but escaped observation, since some of the mutants were not used in propagation of the stock.

"On another point the occurrence of these sexual forms (in the sex-intergrade strain) throws important light on the problem of sex in *Cladocera*, indicating that the capacity for sexual reproduction is not lost after long-continued parthenogenetic reproduction (130 generations). Furthermore, the origin of subsidiary lines within the sex-intergrade strain which produced normal females exclusively (except that in the thirteenth and fourteenth generations of one of these all-female-producing strains several normal males were produced) indicates rather clearly that the sex-intergrade strain did not occur in stock which had lost or had undergone any retrogression in sexual capacity."

The similarity of the general results as to sex obtained by Doctors Riddle and Banta is obvious. Combined with the observations of Goldschmidt on gipsy moths they lead to the conclusion, which Dr. Banta draws, that probably similar but less readily recognizable intermediate sexual states may be of somewhat common occurrence and that sex in general is a much less fixed and precise state than is commonly supposed.

In the case of the sex intergrades of *Simocephalus* it is not maintained that they were brought about by external conditions. They suddenly appeared and were continued because of some change in the germ-plasm. But, as hinted at in Year Book No. 14, page 133, there is evidence that the exclusively female-producing series may be interrupted and males made to appear with special changes in the environment. On this point Dr. Banta reports:

"This evidence came in part from the fact that the very few occurrences of sexual forms among the stock began at times of poor experimental conditions—poor food or otherwise inferior breeding conditions. The sex-intergrade strain originated after the continuation for several generations of conditions unfavorable to *Simocephalus*. One strain of the 'long spine' *Daphnia*, after three or four generations of depression, produced a relatively

large number of males. In one case a 'wild' *Daphnia pulex*, immediately after having been brought under laboratory conditions, produced a large preponderance of males. Some discarded *Daphnia pulex* in a neglected jar long left standing in the laboratory produced males at a time when none of the 18 *Daphnia pulex* lines receiving the usual laboratory treatment showed any tendency to the production of sexual forms. The above were the cases of the occurrences of sexual forms during the past year. The few earlier appearances of sex forms in my cultures were under similar circumstances."

In the sex-intergrade stock similarly modified sex-ratios occurred contemporaneously in the offspring of large numbers of mothers; but whether this result is due to a similar change of environment acting on all lines or to simultaneous mutation is uncertain.

The following lines of *Cladocera* are being bred in Dr. Banta's laboratory:

Species.	No. of strains.	Length of time bred.	No. of generations.		Males.
		months.			
Daphnia pulex	7	58	189 to	201	None } Except in some discarded stock of some of these lines.
	2	18	67	69	None
	3	15	54	60	None
	4	3½	13	17	In one strain, in first laboratory generation.
Daphnia sp. (long spine)	3	34	117	130	Several at two different times.
Simocephalus vetulus	6	49	158	169	In sex-intergrade strain only.
	4	47	158	162	None
	3	34	141	144	None.
	6	21	65	71	None.
Simocephalus serrulatus	5	11	40	44	None.
Moina brachiata	5	14	102	105	None.

"(*a*) These 48 strains of 5 species of *Cladocera* have produced males in only a few isolated instances and under the conditions in the laboratory have shown no evidence of an innate sexual cycle which it is generally supposed exists in *Cladocera*. Strains of four of these species have been reared for over 100 generations solely by parthenogenetic reproduction. One of these species has been reared 169 generations and another over 200 generations, the former for a period of more than four years and the latter for almost five years. If sexual reproduction were necessary or a sexual cycle an innate necessary thing, such ought long since to have become manifest.

"(*b*) In spite of this long-continued and uninterrupted parthenogenetic reproduction these strains show no decrease in reproductive vigor. Tests show that these strains have apparently as great virility and reproductive capacity as 'wild' lines recently brought under laboratory conditions.

"(*c*) These pure lines further serve as material on which to do additional work on inheritance in parthenogenetic reproduction."

SEX IN MUCORS.

Dr. Blakeslee brings to this Station his problem on sexual differentiation in the mucors upon which he has worked for many years; but in adjusting himself to the new conditions he has not found time to work on this topic.

THE INHERITANCE OF GERMINAL PECULIARITIES.

GENETICAL CONSTITUTION OF RUDBECKIA.

Dr. Blakeslee has brought to this Station the investigation of variability and heredity in the yellow daisy (*Rudbeckia hirta*), which he has been making for several years; this year he had under cultivation over 15,000 pedigree plants. He states:

"Variations in the following characters have been found in wild plants: Absence of rays and their presence in rather definite numbers from 8 to 30 and to perfectly double forms; width of rays; diameter of head from 1 to 5½ inches; color of rays from pale straw color to deep orange; relative intensity of color in inner half of ray forming a lighter or darker ring; different intensities of mahogany color at base of ray on upper side; mahogany on under side of ray; constriction of ray at tip, at middle, or at base—those constricted at tip, either rolled in or rolled out to give the "cactus" type seen in dahlias—those constricted at base without change in color or characterized by lighter color or by presence of black pigment on constricted areas; transformation of rays into tubes, giving 'quilled' type; the position of rays, bending upward, horizontal, reflexed, straight, or variously twisted; the shape and size of disk; the color of disk, from yellowish green through several grades of purple to almost black; vegetative characters, such as height, branching, size and shape of leaf, fasciations, etc.

"Evidence from the distribution of the variants in nature and from their reappearance in sowings from open-pollinated heads shows that most if not all of these variations are inherited. Certain of these characters appear to be inherited in simple Mendelian manner; giving 3 : 1 ratios in the F_2 generation. Thus basal 'mahogany' on the ray acts as a dominant, while a type of reddening of the back and base of the ray which I call 'chocolate' acts as a recessive. In both, however, pattern factors undoubtedly exist and are responsible for the extreme variability in arrangement and intensity of the pigment.

"One character, the presence of yellow in place of the normal purple in the cone, has proven of considerable interest. I have obtained this variation from several different localities. The peculiarity seems to be inherited as a simple recessive. The fact, however, that the yellow-coned plants A crossed with B, B with C, or C with A all produce purple-coned offspring shows that the yellow-coned forms are not alike genetically. That they differ chemically is indicated by treatment with KOH when the cone flowers of A turn black and those of B and C turn bright crimson. Since seedlings that are destined to produce yellow cones have no red pigment in their stems, it should be possible to save considerable time by selection in the seed-pans, and my plans therefore are to make a more intensive study of this character the coming season.

"We have some 12,000 plants of the jimson weed (*Datura stramonium*) under cultivation. Two mutations appeared in our cultures last year which are being studied. The first is characterized by a globose capsule and broad leaves and is apparently a recessive. The second has spineless capsules, slit corollas, and lacerated leaves, and is apparently a dominant. The Daturas have not yet been recorded this year, and it is therefore not possible to report upon the behavior of these types in crosses nor of others that are appearing.

"Among other problems under investigation may be mentioned inheritance of self-sterility in *Rudbeckia*, *Helianthus*, and *Verbena*, parthenocarpy in cucumbers, chemical and physical differences between the sexes in diœcious plants, the annual habit in beets, various characters in *Geodetia*, *Clarkia*, *Portulaca*, *Fraxinus*, *Betula*, *Morus*, *Populus*, and *Salix*."

HEREDITY IN MAN.

As was the case last year, the Director's main line of research has been the analysis of data afforded by the Eugenics Record Office as to the inheritance of human traits.

Through the generosity of Mrs. E. H. Harriman and the organization of the Eugenics Record Office, it has been possible to undertake a study of the well-known "Jukes" family from the time of Dugdale's work to the present—40 years later. The investigation was intrusted to Dr. Arthur H. Estabrook. Dr. Estabrook's results have been issued as Publication No. 240 of the Carnegie Institution of Washington. The main conclusions of this paper are:

"On the whole, the later descendants of the Jukes, in Connecticut, in New Jersey, even in Minnesota, still show the same feeble-mindedness, indolence, licentiousness, and dishonesty; even when not handicapped by the associations of their bad family name and despite the fact of being surrounded by better social conditions. This is because, wherever they go, they tend to marry persons like themselves. On the other hand, the dispersion has led some of these descendants to marry into better stocks, and this is improving the quality of the germ-plasm.

"Not merely institutional care, nor better community environment, will cause good social reactions in persons who are feeble-minded or feebly inhibited, although, on the other hand, better stimuli will secure better reactions from weak stock than will poor stimuli."

The whole study will, it is thought, bring home to those interested in social progress the grave importance of the constitutional or hereditary factor in determining behavior.

The Director has been engaged during the year in a study of heredity of human stature, a classical topic of research which offers almost insuperable obstacles to a satisfactory solution in terms of modern genetic theory. To see if various segments of stature, such as head and neck, trunk, thigh, and foreleg, are separately and independently inheritable the Director measured personally two generations in scores of families, chiefly on Long Island, but also in Lexington, Kentucky. The results are being prepared for publication.

The studies of the Director on the inheritance of elements of human behavior are being synthesized in an analysis of the life-activities and output of effective men. This topic demands extensive reading and analysis of biographies and family histories in order to determine the distribution in the family of the significant traits.

HEREDITY IN SHEEP AND POULTRY.

The experiments on heredity of twin-production and multi-nippled condition have been continued. In the spring, from 10 ewes, 22 lambs were born, all multi-nippled. As the ewes have 4 functional mammary glands, they were successful in feeding and rearing their young.

The sheep experiment at the New Hampshire Experiment Station has been continued. A strain of Hampshiredown-Rambouillet hybrids has been nearly perfected, and shows in a high degree a union of especially valuable qualities of fine wool and good conformation. In addition the second hybrid generation of Southdown-Rambouillet origin is being produced.

With poultry we are continuing the prolonged selection for "new buff," studying the factors present in "bare neck," analyzing the genetic constitution of certain new rumpless strains and of syndactylism. There were 184 chicks hatched during the year.

OTHER INVESTIGATIONS.

CORRELATION BETWEEN CHARACTERS OF LEAVES IN NORMAL AND ABNORMAL BEAN SEEDLINGS.

Dr. J. A. Harris has been breeding a strain of beans that produces more than the two primordial leaves that constitute the normal number. His problem was, How do the abnormal and the normal plants compare in respect to total weight of leaves and sap density? The results are as follows: When the cotyledons are of the normal number, 2, but not attached at the same level, the total weight of the leaf laminæ is about 81 per cent of that of strictly normal plants. In a sample of 100 seedlings, selected for greatest separation on the stem of the cotyledons, the ratio is 79 per cent. Where there are 3 instead of 2 cotyledons and 2 primordial leaves the leaf-tissue is about 78 per cent of normal. Even when with 3 cotyledons there are 3 primordial leaves in place of 2, the total weight of their laminæ is 10 per cent less than that of the normals. In fasciated plants about 25 per cent less leaf-tissue is produced than in normals. As for the cell-sap, there is not a marked difference in concentration between normals and abnormals.

CORRELATION BETWEEN HOMOLOGOUS PARTS OF A PLANT.

In plants there is obviously hereditary resemblance between the parts of one and the same plant. Dr. Harris has determined for the legume *Cercis canadensis* the correlations between the number of ovules to the pod, number of seeds to the pod, number of abortive ovules, etc., from different pods of one plant, and has compared his results with figures obtained by other statisticians. The correlation of ovules is higher in *Cercis* than in most other species studied; but the correlation in number of seeds is about the same as obtained in other cases.

VEGETABLE SAPS.

Gortner, Lawrence, and Harris show ("The extraction of sap from plant tissues by pressure," *Biochem. Bull.* No. 5, 139–142) that Dixon and Atkins are indeed right in their caution that a sample of sap

obtained by pressing untreated tissues can not be considered typical of the whole sap of the tissue. The authors show that there is a gradual increase in concentration in successive fractions of the expressed plant-sap.

Harris and Lawrence have also studied the plant-sap in relation to environment on the Arizona deserts, to determine the cryoscopic constants. For the region as a whole the average cryoscopic determinants are: trees and shrubs, 28.10 atmospheres; dwarfs and half shrubs, 27.45 atmospheres; perennial herbs, 16.35 atmospheres; winter annuals, 14.73 atmospheres. In relation to habitat the concentration of plant-juices increases in the following series: arroyos, Pima Cañon, rocky slopes, mesa-like slopes, salt-spots.

TABLE OF OSMOTIC PRESSURE BASED ON DEPRESSION OF FREEZING-POINT.

Dr. Harris has extended a table of osmotic pressures of vegetable saps, based on depression of the freezing-point, from 3.00 to 5.99.

STUDIES IN PERSONAL EQUATION AND STEADINESS OF JUDGMENT.

Dr. Harris, as results of his biometric work, has published two papers in the *Psychological Review*, entitled, "Experimental data on errors of judgment in the estimation of the number of objects in moderately large samples, with special reference to personal equation" (Nov. 1915), and "On the influence of previous experience on personal equation and steadiness of judgment in the estimation of the number of objects in moderately large samples" (Jan. 1916). He reaches the conclusion that errors in estimation (in the case of 50 beans) are due, among other things, to personal equation and steadiness of judgment. In three subjects—

"There is a slight but significant personal equation, which, notwithstanding the constant efforts to improve, persists throughout the two years during which the experiments were intermittently made. For a measure of steadiness of judgment is used the coefficient of variation. The subjects differed more strikingly in steadiness of judgment than in personal equation.

"Personal equation seems to be remarkably little influenced by experience. In some experiments it increases, in others it decreases.

"Steadiness of judgment is in rather conspicuous contrast with personal equation in that it is remarkably influenced by previous experience. The correlations between the number of previous trials within the period and steadiness of judgment and between the number of previous periods within the experiment and steadiness of judgment are numerically low, but almost without exception indicate that as experience becomes greater the scattering of the individual estimates about their mean value becomes less. Probably the rate of this change is not uniform, but is most rapid at first and then falls off."

BIOMETRIC MISCELLANY.

The correlation between a series of measures taken in one year and a series taken a subsequent year may be designated as direct interannual

correlation. Dr. Harris points out the value of knowing the correlation in egg-laying, milk-yield, crop-production, and the like between first and second year, as enabling one to predict the second year's performance from that of the first. A series of illustrative cases is given in "The value of interannual correlations" (*Amer. Nat.*, 49, 707–712).

The distribution and correlation of the sexes (staminate and pistillate flowers) in the inflorescence of certain weeds has been worked out by Dr. Harris (*Bull. Torrey Botanical Club*, 42, 663–673) from data of *Cannarella.*

Dr. Harris has also published "An outline of current progress in the theory of correlation and contingency," in the *American Naturalist* for January. Also a note on "standard dairy score-cards" (*Science*, Oct. 8, 1915).

"The incidence of the beetle *Bruchus* on beans" has been studied incidentally by Dr. Harris. His analysis shows that the larger pods are more apt to be parasitized, probably because of some relation of greater fitness to the size of the beetle.

GENERAL CONSIDERATIONS.

In a subject of such complexity as biology it is often desirable to spend some time in synthetic or general analytic discussion. The Director has written a paper on the topic "The form of evolutionary theory that modern genetical research seems to favor" (*American Naturalist*, Aug. 1916), in which the preformation view of phylogenesis—the view of orthogenesis—is accepted as a very useful hypothesis, and one with the most numerous probabilities in its favor. Some of the evidence for it is set forth and certain consequences of it as a theory.

A second general paper is an effort by Dr. E. C. MacDowell to clear up the differences that have developed between Castle and other geneticists, or rather to harmonize Castle's views with current theory. This paper, "Piebald rats and multiple factors," appeared in the *American Naturalist*, December 1916.

The Whitman manuscripts have been brought forward by Dr. Riddle, and, it is expected, will be completed by the end of the year.

GEOPHYSICAL LABORATORY.*

ARTHUR L. DAY, DIRECTOR.

THE IRON OXIDES.

The great importance of the iron oxides and silicates as components of the common rock-forming minerals was pointed out in the annual report for 1905, and work was begun on ferrous silicate in that year.[1] But difficulties were encountered in obtaining data that could be interpreted, and the problem was held in abeyance while the more easily accessible lime and magnesia silicates were being studied in detail. Two years ago the problem was again taken up.

The most important fact in connection with the study of the oxides and silicates of iron is that gaseous oxygen must be considered as an essential component. The other common rock-forming oxides (silica, alumina, magnesia, lime, and the alkalies) can be treated as members of condensed systems in which the relations are practically unaffected by the presence or absence of atmospheric gases. The equilibrium between ferric and ferrous iron, on the other hand, can vary with every change of temperature and with every change in the amount or pressure of available oxygen. The relations of the oxides and silicates of iron can therefore be worked out only in apparatus in which the pressure of oxygen is under quantitative control. Apparatus for this purpose has been built and tested and has been described in a previous report.[2]

The first phase of the problem is the study of the oxides of iron. The properties of ferrous silicate, for instance, can best be worked out by considering it as a compound in the three-component system silica-iron-oxygen. Therefore the two-component system iron-oxygen must first be understood. This system in itself is of very great importance, because metallic iron is manufactured almost exclusively from oxide ores. The properties of the iron oxides are therefore of fundamental importance to the iron and steel industry, and the genetic problems of the iron ores, both hydrated and anhydrous, form a subject of constant discussion among economic geologists.

Ferric oxide (hematite) dissociates at high temperatures, giving off oxygen and leaving a homogeneous product which may be considered as a solid solution of magnetite (Fe_3O_4) in hematite (Fe_2O_3). The proportion of magnetite in the product depends upon the temperature and upon the oxygen pressure above the oxide. The lower the oxygen pressure and the higher the temperature, the more magnetite is found in the solid solution. The reaction is strictly reversible, for magnetite

[1]Year Book 4, page 228 (1905). [2]Annual report, 1915, papers (9) and (10).

*Situated in Washington, D. C.

readily takes up oxygen at temperatures above 300° until the equilibrium proportion at the temperature in question is attained. Magnetite is therefore a chemically unstable mineral under atmospheric conditions, although it may remain unoxidized for long periods, just as the physically unstable forms of silica (tridymite, cristobalite) and of calcium carbonate (aragonite) persist unchanged at ordinary temperatures after they have once been formed.

The dissociation pressure of magnetite is extremely low, yet it also can be dissociated at high temperatures under low oxygen pressure. The product is intermediate in composition between Fe_3O_4 and FeO, but the exact relations are not yet determined. The properties of ferrous oxide also are as yet little known. Most of the published methods for preparing FeO yield only a mixture of metallic iron and an oxide intermediate in composition between FeO and Fe_3O_4. The opacity of all these products deprives us of the valuable aid usually obtained from the petrographic microscope.

Practically all natural iron oxides, hydrated or anhydrous, contain a determinable amount of ferrous iron. The proportion ranges all the way from a few hundredths of 1 per cent of FeO, in some hematites, up to the percentage in pure magnetite. The amount and manner of combination of this ferrous iron give important indications of the origin and history of the oxide, as may be readily seen from chemical considerations. Ores formed by the simple hydrolysis at low temperatures of ferric compounds will contain practically no ferrous iron. Hematites of magmatic origin may contain several per cent of FeO. A particularly interesting feature of the latter is the occasional zonal distribution of the ferrous iron occurring, for instance, in hematite crystals from the ore deposits of Elba. This zonal growth shows clearly that the temperature or the oxygen concentration, or both, were changing continuously in one direction during the deposition of these crystals.

Ferric oxide exhibits a reversible thermal inversion-point at about 680°, corresponding to a magnetic inversion which was already known. Analogous magnetic inversions occur in metallic iron and in magnetite, although at different temperatures and with a very much greater change in magnetic susceptibility. Some intimate atomic relationship undoubtedly exists among these inversions in iron and its oxides, from which increased light on the atomic constitution of the oxides and the nature of chemical valence may some day be obtained.

The magnetic properties of the oxides offer a most interesting field for investigation from the standpoint both of geology and of pure physics. The attraction exerted upon a given weight of oxide by a magnet is almost directly proportional to the percentage of FeO in solid solution through the range of compositions from Fe_2O_3 to Fe_3O_4. Ferrous oxide not in solid solution in the oxide, however, as in some

limonites, has almost no magnetic effect. We have here, in the magnetic susceptibility, a criterion of origin to add to the ferrous iron percentage.

Although ferric oxide has commonly a very low magnetic susceptibility, yet it can be obtained with a susceptibility of the same order of magnitude as that of magnetite itself by the slow oxidation of magnetite at low temperatures. One natural example of this "true magnetic hematite" (as distinguished from the common magnetic hematite whose magnetism is due to ferrous iron) has been found. This peculiar persistence of magnetic properties in spite of a radical change in the chemical composition points to some fundamental atomic origin for the phenomena of magnetism, which can perhaps be approached through the study of these oxides.

There is still another magnetic property about which we know practically nothing in the natural oxides of iron, namely, polarization or permanent magnetization. Natural magnets of varying strength are frequently found in magnetite deposits, although the bulk of such deposits are entirely unpolarized. These differences show that different conditions of origin and history have undoubtedly existed, whose elucidation waits upon physical and chemical study of the artificial oxides in the laboratory.

A beginning has been made upon the polycomponent systems containing ferric oxide as one component, in the investigation of the system $CaO–Fe_2O_3$. Only two compounds occur in the system: $2CaO.Fe_2O_3$ and $CaO.Fe_2O_3$. Both dissociate before melting; the former at 1436° and the latter at 1216°. The eutectic between Fe_2O_3 and $CaO.Fe_2O_3$ melts at 1203°. All mixtures between about 15 and 25 weight per cent CaO, therefore, melt within a few degrees of 1200°. The properties of this system are of interest in connection with portland cement, in which a small proportion of Al_2O_3 is frequently replaced by Fe_2O_3; and also as a partial basis for the study of various metallurgical slags.

Progress has also been made in the characterization of the different crystalline hydrated ferric oxides, in connection with the work on secondary enrichment of sulphide ores.

CALCIUM CARBONATE.

Calcium carbonate is without doubt the most important individual constituent of the sedimentary deposits, and its mode of deposition has been discussed, primarily or incidentally, in a very large number of papers. Nevertheless, despite the attention bestowed upon this topic, there remain inconsistencies and gaps in our knowledge of it. In the consideration in this laboratory of the deposition of calcium carbonate, to which reference was made in the annual report for 1915

(Year Book No. 14, p. 154), attention has been concentrated upon two points in particular: (1) the appearance of $CaCO_3$ in forms other than calcite and the conditions under which such other forms may appear and persist; (2) the solubility of calcium carbonate under various conditions, with particular attention perhaps to its concentration in and eventual deposition from sea-water. Of the forms other than calcite the only one of geologic importance at present is aragonite; but, by reason of the fact that aragonite is an unstable form, it is not feasible to specify the conditions which really determine its appearance. Organic agencies are doubtless responsible for a great part of the aragonite found in nature, but there is no question that it may sometimes be precipitated in other ways, either at the higher temperatures or in the presence of certain salts. This work, therefore, though it has cleared up a number of points which hitherto have been obscure, has not yet enabled us to make definite, positive inferences from the association in which aragonite is found in particular localities.

As a result of the recalculation of the solubility data, the solubility-product constant of calcite can now be regarded as established with sufficient accuracy, and it is now possible in consequence to compute the solubility of calcite under any conditions ordinarily met with in nature. Comparison of the results of such computations with the available analytical data has led us to the belief that the warm portions of the ocean-water are substantially saturated with calcite, a belief which carries with it important implications. Of these, two may be mentioned, namely, (1) that, wherever the sea-water is saturated with calcite its degree of alkalinity is fixed thereby, and (2) that abstraction of CO_2 from the water, by whatever agency achieved (*e. g.*, by a slight diminution in the CO_2 content of the superjacent air), must result in the precipitation of a definite quantity of $CaCO_3$. It also follows directly that such water would be a very efficient regulator of the amount of CO_2 in the atmosphere. The complete validity of this conclusion ought not, perhaps, to be regarded as definitely established until more accurate determinations have been made upon sea-water from a wide range of localities; the only data now available were obtained from a somewhat restricted region and their accuracy leaves much to be desired. Particularly is this true with regard to the various existing determinations of CO_2, bound and free, when examined in the light of the conditions of equilibrium involved in such determinations. But these errors are no longer unavoidable, and it is greatly to be hoped that a systematic investigation of the ocean-waters from this viewpoint may be undertaken in the near future. Such an investigation is highly desirable by reason of its bearing upon many biological questions as well as upon the important geologic problems which we have considered.

VOLCANIC GASES.

The gases which emanate from the lava basin at Kilauea have been found on analysis to consist primarily of free sulphur, free hydrogen, CO_2, SO_2, CO, H_2O, and N_2 in varying proportions, but the limits of variation are such as to indicate that the chief gas-reactions which are taking place there are these:

1. $4CO+2SO_2 \rightleftarrows 4CO_2+S_2$ (*a*) $2CO+S_2 \rightleftarrows 2COS$.
2. $4H_2+2SO_2 \rightleftarrows 4H_2O+S_2$ (*a*) $2H_2S \rightleftarrows 2H_2+S_2$.
3. $H_2+CO_2 \rightleftarrows H_2O+CO$.

At the outset of our investigation of these gas relations, the water-gas reaction (3) had been studied (Haber) and could be accounted established. The dissociation of hydrogen sulphide (2*a*) had also been determined, but the literature bearing on the other reactions was meager and contradictory. Some of the chemical constants of SO_2 were also unknown, so that it was quite impossible to calculate, even approximately, the reactions 1 and 2. The paucity of our knowledge of a gas so important, both scientifically and technically, as SO_2, indicated at the outset that many difficulties lay in wait for the investigator in this field.

In passing it may also be noted that a successful study either of reaction 1 or reaction 2 would render feasible a calculation of the other with a fair degree of accuracy and also would give the much-desired data concerning SO_2.

After preliminary investigation, the reduction of SO_2 by CO, *i. e.*, reaction 1, was selected for study, for the reason that it seemed to present less experimental difficulty than the other, and also because it is itself the basis of many of the sulphur-recovery processes used in the industries and is therefore not altogether unfamiliar.

The usual analytic methods were not immediately applicable, nevertheless, for while methods of detecting small amounts of the gases involved are known, they are not suitable for the accurate determination of their amounts. The necessity which thus arose for the development of new methods and apparatus had to be met before any advance could be made upon the real problem.

From the nature of gas-reactions it is evident that great difficulties will always attend the procuring for analysis of volcano-gas samples which can be assumed to retain the original composition which they had in the reaction-chamber at the high temperatures there prevailing. There is also the difficulty of differentiating between changes due to cooling and those due to catalysis when it happens that these changes are in the same direction, as in reaction 1. Fortunately, it was found[*] that they are not in the same direction in the case of the subsidiary reaction

(1*a*) $$2CO+S_2 \rightleftarrows 2COS.$$

Studies of mixtures in which this reaction participates are therefore competent to clear up this phase of the problem.

This is a conclusion of prime importance, for had there been any uncertainty upon this one point, or had the issue perchance turned out otherwise, the integrity of the test material and the possibility of reaching definite conclusions regarding the reactions within this particular group of gases at the temperatures and under the conditions obtaining in an active volcano were vitally threatened.

The detailed study of the reaction 1(*a*) was accordingly undertaken, and the investigation at one temperature (1000°) may now be considered successfully completed. The work is to be extended to higher temperatures for the purposes of obtaining confirmatory data, but there is no longer any reason to anticipate possible failure, nor, indeed, any undue delay in obtaining a solution for this very difficult problem.

This information when obtained will enable us to indicate the rôle which these gas-reactions play in volcanic activity like that at Kilauea, and to settle the question whether or not they are to be regarded as the source of any considerable portion of the energy dissipated there. The preliminary data at present available confirm the view set forth in Year Book No. 12, page 128, namely, that a considerable portion of the energy of volcanic activity originates in the gas-reactions within the magma chamber and its various outlets.

Field observations of different phases of volcanic activity have been made within the year at Stromboli and Vesuvius in Italy, at Lassen Peak in northern California, and at Kilauea and Mauna Loa on the island of Hawaii. Lassen Peak appears now to have concluded the period of explosive activity which began so unexpectedly in May 1914. The visible activity on the mountain during the past season was confined to steam fumaroles, in which feeble traces of HCl and H_2S were occasionally to be detected. Perhaps in compensation for the absence of explosive phenomena, the hot springs at the base of the mountain afforded a splendid opportunity to study natural pyrite formation in all its phases, of which full advantage was taken.

The eruption of Stromboli during the autumn and early winter of 1915 proved to be unusual both in character and intensity. On several occasions during nearly five months of activity, lava flowed down the Sciarra from the principal vent to the sea in continuous streams. Opportunities to see a stream of incandescent lava in contact with water have been rare in the history of modern volcano study. Both at Stromboli and at Sakurashima in 1914 liquid lava was observed to continue its flow under water without explosive violence, or indeed any manifestation whatever, at the surface of the water, of what was taking place below. A quickly cooled porous sheath of quasi-flexible, vitreous lava forms about the stream, which is sufficiently non-conducting to confine the great body of heat within the flowing stream and to release it gradually. The immediately adjacent water showed but a few degrees rise in temperature. No gas-bubbles reached the surface.

This eruption also afforded opportunity to correct a long-standing misconception of the significance of certain cloud phenomena commonly observed and recorded. The density of the cloud which emerges from the crater is by no means always a measure of the activity within, and indeed sometimes bears no relation to it. The approach of a cold, moisture-laden wind causes an immense apparent increase in the volume of emerging "smoke," which has no other origin than the condensation of the moisture by volcanic emanations. When the atmosphere chances to be near the saturation-point it will condense in massive white cumuli on coming within range of the volcanic dust, which gives the impression of a great increase of activity without any change whatever in the conditions within the crater. This observation vitiates in large measure the usefulness of any continuous record of volcanic activity which is based upon the apparent volume or height of the cloud from day to day.

At Vesuvius there is at present continuous activity in two adjacent openings in the crater floor about which a cone of scoriaceous matter and lava-splashes has formed which has now reached a height of about 85 meters. The crater floor itself is also rising slowly. In company with Professor Malladra, Director of the Vesuvius Observatory, and guides, Mr. Perret found it practicable to reach the crater floor and to collect both gaseous and liquid ejecta for laboratory study.

It is a very great misfortune that this period of unusual activity, in which all the active Italian volcanoes appear to be participating, happens to fall in a period of political upheaval, one consequence of which is to impose prohibitive limitations upon the movements of foreigners. It is at the moment practically impossible to continue effective field studies in Italy.

In Hawaii, both at Kilauea and Mauna Loa, there has been paroxysmal activity in recent months, and from Mauna Loa a considerable outflow of lava in June of this year. A radial crack opened about half-way up the mountain and from it streams flowed both east and west for a distance of about 8 miles. The flow continued for 6 days only and occurred in a barren and rather inaccessible part of the mountain, so that even the experienced men who chanced to be within reach found difficulty in reaching advantageous points for study and collection during the period of actual flow. Later the sources of the new flow were examined with care, but the gaseous portion of the ejectamenta had then flown and left an irreparable gap in the chemical data available for further study.

In spite of these various limitations, which are of course inevitable in the study of volcanoes, the elucidation of the volcano problem has made considerable progress during the past year, of which a detailed record will presently be published.

PUBLICATIONS.

Brief reviews of the papers published by members of the Laboratory staff during the current year follow.

(1) The position of the vibration plane of the polarizer in the petrographic microscope. F. E. Wright. J. Wash. Acad. Sci., 5, 641–644 (1915).

In petrographic microscopes the polarizer is mounted in one of two positions, so that its plane of light transmission is parallel either to the vertical cross-hair or to the horizontal cross-hair of the eyepiece. In case the incident light be non-polarized both positions of the polarizer are equally good, as they transmit equal amounts of light. If, however, the incident light be partially polarized, that position of the polarizer which transmits the most light is obviously the better. Partial polarization arises from two factors: (1) Reflection by the surface of the substage mirror. This is not serious, because under ordinary conditions less than 10 per cent of the light thus reflected is plane-polarized. (2) Sky polarization. This varies with the line of sight and is at a maximum in the plane polar to the sun. On a clear day from 40 to 80 per cent of the light is plane-polarized in this plane, which is also the plane of vibration of the polarized rays. As this plane moves with the sun, the plane of vibration of rays incident on a microscope facing north is nearly vertical in the early morning and later afternoon hours, while at noon it is horizontal. The optimum position of the polarizer varies, therefore, with the time of day at which observations are made. In case the polarizer is fixed in position, its plane of vibration should be parallel to the vertical cross-hair of the eyepiece.

(2) The later stages of the evolution of the igneous rocks. N. L. Bowen. J. Geol., 23, Suppl., 1–91 (1915).

With the continuance of experimental studies of silicate melts, systems have been investigated which approach in their complexity some of the simpler types of igneous rocks. As a result, new light is thrown on some of the problems of igneous-rock genesis, and in this paper an attempt has been made to discuss these problems with the emphasis placed on the significance of the experimental studies.

Of all the processes that have been suggested as important factors in the differentiation of rocks, crystallization alone seems to be thoroughly competent to produce large results. The formation of various rock types through the agency of crystallization depends on the fact that the various minerals in a fused mixture separate in a definite order, and that during the period of crystallization an accumulation of crystals of a certain kind may take place in one part of the mass with corresponding impoverishment of this material in other parts. The accumulation of crystals is believed to take place largely through the action of gravity. Experimental evidence shows definitely that the sinking of crystals in silicate melts can take place and a variety of field observations indicate its importance in nature.

The crystallization of mixtures containing a number of important rock-forming silicates has been very thoroughly studied. These silicates include, among others, the plagioclases, pyroxenes, olivines, spinel, and silica in its various forms, and the order of their appearance for various mixtures has been definitely ascertained. The order shows plainly that, under the action of gravity, there would be a definite tendency towards the grouping of the olivines, pyroxenes, spinel, and the basic plagioclases in the differentiates of early consolidation, with a resultant enrichment of the later differentiate in alkaline feldspars and free silica. This is the kind of differentiates we find in nature in the gabbro-diorite-granite sequence.

The method of differentiation by sinking of crystals seems, then, to afford a promising explanation of the subalkaline series of igneous rocks. With the alkaline rocks many features are more obscure, but the formation of the hydrous molecules which enter the micas in the later members of the subalkaline series strongly suggests that the alkaline types belong in this late stage of great concentration of the volatile ingredients of the magma, especially water. The mica molecules, for example, are very closely related in type to the molecules of nephelite, the most characteristic mineral of the alkaline rocks.

On the basis of these deductions from experimental results, it is concluded that all igneous rocks could be derived from basic magma, and the hypothesis is advanced that all igneous types actually have been derived from basaltic magma by the process of crystallization-differentiation.

(3) The correlation of potassium and magnesium, sodium and iron, in igneous rocks. H. S. Washington. Proc. Nat. Acad. Sci., 1, 574-578 (1915).

The fact that these pairs of elements are correlated, or tend to vary together, in igneous magmas irrespective of the silicity, is briefly discussed and some of the evidence given. The correlation is shown in the minerals of igneous rocks. Thus the sodic pyroxenes and amphiboles are very high in iron and very low in magnesium, while on the other hand the colored potassic micas usually show very high magnesium and low iron. It is pointed out that in igneous rocks there are no potassic pyroxenes or amphiboles, and no sodic micas. The evidence from the rocks themselves is based on a collection of nearly 10,000 analyses. A number of examples of petrographic provinces are given, and many analyses are plotted which bring out clearly the correlation.

(4) A simple device for the graphical solution of the equation $A=B.C.$ Fred. E. Wright. J. Wash. Acad. Sci., 6, 1-5 (1916).

In this equation, which is essentially a simplified form of the proportion $A:B=C:D$, the letters may represent numbers, or powers of numbers, or functions of variables, sines, cosines, tangents, logarithms, exponentials, etc. The graphical method of solution adopted is based on similar triangles, each function A, B, and C, being represented on a scale so chosen that the resulting curves are straight lines. A device is suggested for the mechanical solution of this general equation. At one corner of a sheet of 1 mm. coordinate paper, 50 cm. square, attached to a small drawing-board, a straight-edge is fitted into a socket and can be rotated about the corner as axis. Along the two adjacent margins of the paper a strip of millimeter paper is pinned, and on it the scale A or B is marked. The straight-edge functions as the hypothenuse of the similar right-angle triangles employed in the graphical solution. The device is accurate to about 1 part in 1,000.

(5) A geological protractor. Fred. E. Wright. J. Wash. Acad. Sci., 6, 5-7 (1916).

By means of this protractor angles of dip and strike can be plotted as with the ordinary protractor; in addition, slope angles (angles of apparent dip for any angle of dip of stratum and for any azimuth of vertical section) can be read off directly; the protractor can also be used as a hand goniometer for the measurement of crystal angles.

(6) The ternary system $CaO-Al_2O_3-MgO$. G. A. Rankin and H. E. Merwin. J. Am. Chem. Soc., 38, 568-588 (1916).

No ternary compound stable in contact with the melt was found, therefore the system involved only the equilibrium of the components and the binary compounds $3CaO.Al_2O_3$, $5CaO.3Al_2O_3$, $CaO.Al_2O_3$, $3CaO.5Al_2O_3$, $MgO.Al_2O_3$. A new form of Al_2O_3 was described, but its relation to corundum (the only

other known form of Al_2O_3) could not be definitely established. Extensive solid solution of Al_2O_3 in spinel was demonstrated. Only slight solid solution was observed in any other crystals. Diagrams and a solid model were made to show the relations found.

(7) Das ternäre System: $CaO–Al_2O_3–MgO$. G. A. Rankin und H. E. Merwin. Z. anorg. Chem. (In press.)

A German translation of "The ternary system $CaO–Al_2O_3–MgO$." (J. Am. Chem. Soc., 38, 568–588, 1916). Reviewed under No. 6 above.

(8) A universal switch for thermoelement work and other potential measurements. Walter P. White. Am. J. Sci. (4), 41, 307–316 (1916).

A switch combination is described which is intended to promote rapidity (and, therefore, often accuracy also) in making comprehensive and varied measurements with potentiometers. The type is characterized by the use of contacts between thin copper strips, which is, thermoelectrically, perhaps the best contact obtainable. A new mechanical arrangement greatly promotes convenience and flexibility in operation. Other schemes make construction and overhauling extraordinarily easy.

(9) The charnockite series of igneous rocks. H. S. Washington. Am. J. Sci. (4), 41, 323–338 (1916).

The name was applied by Holland to an important and interesting series of igneous rocks in southern India, ranging from hypersthene granite (charnockite) to hornblende hypersthenite. Five type specimens, furnished by the India Geological Survey, were studied and four complete analyses were made. The rocks form a distinct series, characterized by certain constant mineral and chemical peculiarities. Closely allied to the Indian comagmatic region are those of western Norway, Ellesmere Land, eastern Canada, New York State, and the Ivory Coast. The relations of these are discussed and the suggestion is made that the rocks of all these comagmatic regions can not be placed logically in either the Atlantic or Pacific tribes of Becke and Harker.

(10) The oxides of iron I. Solid solution in the system $Fe_2O_3–Fe_3O_4$. R. B Sosman and J. C. Hostetter. J. Am. Chem. Soc., 38, 807–833 (1916).

This investigation of the chemical relationships of the iron oxides has been undertaken as a basis for the study of the iron-bearing silicates at high temperatures. Measurements of the dissociation pressure of the iron oxides were made in a vacuum furnace with a heating tube of platinum-rhodium.

A study of the conditions of equilibrium shows that reproducible oxygen pressures can be obtained at a given temperature. Equilibrium is attained in a few minutes at high temperatures, although certain disturbing reactions go on slowly. One of these by-reactions is the reduction of the oxide by platinum, yielding oxygen and an iron-platinum alloy. This reaction accounts for the common occurrence of iron as an impurity in platinum.

Ferric oxides from various sources yield practically identical pressures (excluding certain minor exceptions which can not as yet be explained). The same pressures are also attained with both rising and falling temperatures. The oxidation of magnetite gives pressures which are identical with those produced by dissociation of pure Fe_2O_3.

The pressure-composition isotherm for the system $Fe_2O_3–Fe_3O_4$ at 1200° indicates a continuous solid solution series from Fe_2O_3 over to a point very near Fe_3O_4, if not over the entire range to Fe_3O_4. The opacity of the products prevents an optical demonstration of the existence of solid solution in products with more than 18 per cent FeO, but its existence can be shown optically in

products which are more ferric than this. The pressure-composition isotherm at 1100° confirms that at 1200°.

The major portion of the oxygen pressure curve of the system at 1200° lies between the limits 4 mm. and 1 mm. The pressure drops rapidly near Fe_3O_4 and rises rapidly near Fe_2O_3.

Since the dissociation of Fe_2O_3 results in the formation of a solid solution, the pressure of oxygen and the composition of the solid phase depend upon the relation of the weight of the charge to the volume of the space into which the oxygen dissociates. This fact accounts for the variety and uncertainty of results heretofore obtained in experiments on the dissociation pressure of Fe_2O_3.

(11) The dissociation of ferric oxide in air. J. C. Hostetter and R. B. Sosman. J. Am. Chem. Soc., 38, 1188-1198 (1916).

Previous work by the authors has shown that Fe_2O_3 dissociates to form a solid solution of Fe_3O_4 in Fe_2O_3, and that the curve of dissociation pressure against composition at a given temperature rises rapidly as the composition approaches pure Fe_2O_3. The present experiments show that there is a measurable dissociation of Fe_2O_3 in air at all temperatures between 1100° and 1300°, and that the amount of dissociation increases with the temperature. This is shown by the increasing difference in weight between ignitions in air and in oxygen as the temperature is increased. The dissociation pressure-composition curve thus takes the form of a curve asymptotic to the axis of ordinates, when the ordinates are pressures.

The best container for the Fe_2O_3 at 1100° and 1200° is alundum (bonded fused alumina) which is almost absolutely constant in weight at these temperatures, although it loses weight steadily at higher temperatures. The loss in weight of pure platinum at 1000° to 1200° is very small, but is considerably increased if the platinum is in contact with ferric oxide.

(12) The determination of carbonic acid, combined and free, in solution, particularly in natural waters. John Johnston. J. Am. Chem. Soc., 38, 947-975 (1916).

Owing to the importance, especially in connection with water analysis, of a knowledge of the concentration of carbonic acid, combined and free, in solution, a great deal of attention has been devoted to methods of determination of these constituents; but the question as a whole has hitherto received scant attention, in particular from the theoretical standpoint. The present paper discusses the methods of estimating carbonic acid and carbonate on the basis of fundamental principles; this enables us to criticize and coordinate apparently contradictory statements recorded in the very voluminous literature on this subject; for this conflict is due less to lack of care in the experimental work than to the fact that some essential factor, the importance of which, however, would not be recognized until the theory had been considered, was not adequately controlled.

Within any solution containing carbonate there is a readily attained equilibrium between the carbonate ion $CO_3^{=}$, the bicarbonate ion HCO_3^{-}, and the carbonic acid H_2CO_3, and in turn between the carbonic acid and the partial pressure of carbon dioxide above the solution; consequently these molecular species can coexist only in definite proportions determined by the several equilibrium constants. An examination from this standpoint of the most commonly used titration methods for the estimation of the combined and free CO_2 in solution leads to the conclusion that many of these procedures do not yield definite results—a conclusion corroborated by all of the careful comparative experimental work bearing on these methods. In principle the only absolutely reliable methods are those for the total base combined with the

carbonic acid and for the *total* CO_2 present in solution; in practice they yield accurate results, provided that due attention is paid to conditions discussed or referred to in this paper. But these two determinations suffice in general to characterize the solution with respect to either its content of free CO_2, the proportion of carbonate or bicarbonate, or the degree of alkalinity or acidity; for, since we are dealing with an equilibrium capable of fairly rapid readjustment, we are justified in applying the equilibrium constants to calculate the above quantities in the great majority of those cases in which a knowledge of them is of real importance.

(13) The complete solubility curve of calcium carbonate. John Johnston and E. D. Williamson. J. Am. Chem. Soc., 38, 975–983 (1916).

A further development of the views discussed in an earlier paper (Year Book No. 14, page 168). The graph showing the concentration of calcium in the solution at equilibrium in the system $CaO-H_2O-CO_2$ is made up of three curves, along which the stable solid phase is hydroxide, carbonate, bicarbonate, respectively. The first extends only up to values of P, the partial pressure of CO_2, of about 10^{-14} atm. at 16°; the second, starting from the transition-point, decreases to a minimum and then rises again, as the value of P increases continuously, until P is about 15 atm.; beyond the second transition-point bicarbonate is the stable solid phase. Along the whole course of the graph, all three ions OH^-, $CO_3^{=}$, HCO_3^- are present at relative concentrations depending upon P; so in this, as in other analogous cases, the solubility curve ascertained by experiment would have different forms according as one determined one or other of the several molecular species in solution. Thus the maximum concentration of $CO_3^{=}$ occurs when the solubility—as measured by the concentration of calcium in solution—is a minimum, and it is only within a restricted range of P that the base associated with $CO_3^{=}$ is more than a fractional proportion of the total base in solution.

The transition pressure at which both hydroxide and carbonate are stable may be calculated either from the solubilities of hydroxide and carbonate or from their thermal dissociation pressures; these two absolutely independent methods yield results surprisingly concordant, a circumstance which demonstrates the essential correctness of the view discussed in this paper.

(14) The several forms of calcium carbonate. John Johnston, H. E. Merwin, and E. D. Williamson. Am J. Sci. (4), 41, 473–512 (1916).

The prevalence of calcium carbonate as a constituent of the crust of the earth has led to a vast amount of discussion of the chemistry of its formation and of the stability relations of the several crystalline forms in which it occurs. The value, alike to the geologist and to the chemist, of an exact knowledge of the facts has also been repeatedly emphasized. The evidence has, however, been incomplete and in part contradictory or wrongly interpreted, and has never been presented systematically. It appeared, therefore, to be a useful task to give a coherent critical statement of the facts and to discuss the deductions which, in the light of present knowledge, may legitimately be drawn from them.

Under ordinary conditions, calcium carbonate appears in three crystalline anhydrous forms, viz, as calcite, aragonite, and a form which we have designated μ-$CaCO_3$. The other reputed forms, including "vaterite" and "amorphous" $CaCO_3$, are not definite forms; their divergent properties are due mainly to differences in size of grain and mode of aggregation.

Of these three established forms calcite is, at ordinary pressure, the stable one at all temperatures from 0° (or lower) up to 970°, at which temperature it

inverts reversibly to α–$CaCO_3$; under these conditions aragonite and the μ-form are always unstable with respect to calcite, though there is an indication that aragonite has a stable field of existence at about $-100°$ or lower. Under all ordinary conditions, therefore, pure aragonite tends to go over into calcite; in how far it actually does so depends upon the rate of this process under the particular circumstances. There is therefore no definite transition-point; the interval required for the transformation at 100° in presence of water and calcite is measured in days, and for its inversion at or about 400° is measured in hours. By reason of this instability, one can not specify the factor or factors which determine the precipitation of $CaCO_3$ as aragonite; indeed, its appearance would seem to be a matter of chance—in other words, it depends upon factors which can not be controlled at the present time. In so far as we have been able to ascertain, natural aragonite is formed (*a*) through organic agencies; (*b*) by deposition from hot springs; (*c*) when an isomorphous carbonate is present to serve as nucleus; (*d*) in salt waters containing sulphate even at ordinary temperature. Pure aragonite can persist as such only when dry; but aragonite containing other substances in solid solution may thereby be enabled to persist in presence of certain solutions. There are indications that the μ-form often occurs as an intermediate step in the precipitation of the other forms; but it soon transforms in presence of water, a fact which, combined with the fact that it can not be differentiated from aragonite by means of the usual color-tests, is responsible for the circumstance that it has not been recognized more often as occurring in nature.

The properties of these three forms, and of the hexahydrate $CaCO_3.6H_2O$ (which, moreover, is also unstable with respect to calcite even at 0°) are described. The several forms can be differentiated from one another by optical, crystallographic, and chemical tests, by observation of density and of the stability of the material when heated; but it is not safe to trust to a single one of these tests, especially with fine-grained material, as the result may be ambiguous. Much of the work in the past is vitiated by the fact that the criteria employed were insufficient to differentiate one form from another; and thus many of the statements to be found in the literature require revision. In this connection, we might point out that a determination, no matter how carefully carried out, of a single property of a substance is of much less value than two or more characteristics of the same specimen; and make a plea for the determination on an analyzed specimen of as many diverse properties as possible, for it is only in this way that it will be possible to coordinate the various observations in a satisfactory way. As an illustration of this point, one can not state the manner in which the properties of so well-defined and common a mineral as calcite vary with the presence of other substances in it, in spite of the enormous number of isolated observations which have been made; and it is obvious that such a coordination, once established, would save an immense amount of labor thereafter.

(15) The composition of natural bornite. E. T. Allen. Am. J. Sci. (4), 41, 409–413 (1916).

Analyses of a number of bornites from very widely separated localities, the essential homogeneity of which had been proved by a careful microscopic examination of several polished surfaces, were found to agree closely with the formula Cu_5FeS_4. The conclusion is supported by the constancy in the color and density of the specimens. A critique of previous work on the subject is given, and in particular it is shown why the evidence against this view presented by Kraus and Goldsberry (Am. J. Sci. (4), 37, 539, 1914) is inconclusive. The conclusion reached confirms that of Harrington (Am. J.

Sci. (4), 16, 151, 1903), viz, that natural bornite is of constant composition represented by the formula Cu_5FeS_4.

(16) Types of prismatic structure in igneous rocks. R. B. Sosman. J. Geol., 24, 215–234 (1916).

From the physical standpoint, several types of prismatic structure in igneous rocks can be distinguished. The first and most common is due purely to thermal contraction in the crystallized rock; examples are numerous and familiar. A subordinate type of contraction structure is produced when the contraction and separation occur while the magma is still partly crystalline and partly liquid; this type is illustrated by an occurrence in a diabase sill in eastern Pennsylvania.

The second general type is produced by convectional circulation of the magma while still liquid. The cells so produced persist until solidification begins, and may leave a record in the rock, either by causing segregation in the cell walls and axes or by originating regularly spaced centers of crystallization. The experimental and observational data on the occurrence of this type in igneous rocks are suggestive, but can not yet be said to amount to decisive proof.

A third type of prismatic structure is produced by internal expansion. It has been produced artificially, and is offered as the explanation of the "weather-crack" structure seen in diabase boulders.

In the study of these structures, the following field observations are those which will be of greatest interest in the further study of the problem: (1) attitude of prisms; (2) their diameter and length; (3) frequency of 4, 5, 6, and 7 sided polygons; (4) frequency of angles (especially 90° and 120°); (5) variation, if any, of composition and texture in the cross-section; (6) types of cross-jointing (platy, concave or convex, spheroidal); (7) spacing of cross-joints; (8) peculiarities of cross-joints (*e. g.*, whether cracked from center or from borders); (9) degree of irregularity in sides of prisms; (10) other peculiarities, such as tapering, partial longitudinal jointing, etc.

(17) Note on the linear force of growing crystals. George F. Becker and Arthur L. Day. J. Geol, 24, 313–333 (1916).

In 1905 the authors showed by appropriate experimental evidence that a single crystal immersed in its own saturated solution, and growing by reason of the potential supersaturation of the solution resulting from evaporation, will lift a weight placed upon it. This observation has been confirmed in the present paper.

In 1913 Bruhns and Mecklenburg placed two crystals in a similar saturated solution, one loaded and the other free, and noted that the load upon the one crystal was not raised, although the free crystal grew rapidly. From this experiment they were led to deny the power of a crystal to lift a weight of foreign substance, although admitting the power of the unloaded crystal to lift its own substance. They appear to have overlooked in this conclusion the fact that the solubility of the loaded crystal is for most substances greater than that of an unloaded one, and also that this is a difference in degree only, for the unloaded crystal also supports weight (its own).

In consequence of this greater solubility, with an unloaded and a loaded crystal in the same solution, the necessary condition of potential supersaturation will be reached in the liquid adjacent to the unloaded crystal before it is reached in the other, and the growth of the unloaded crystal thereafter may keep the concentration below that necessary for the growth of the loaded crystal. This appears to be the condition reached in Bruhns and Mecklenburg's experiment. If it happens, however, that the rate of growth of the

unloaded crystal is insufficient to take up all of the excess concentration provided by the continued evaporation, then supersaturation will increase. It is entirely possible under these conditions that the potential supersaturation necessary for the growth of the loaded crystal may then be attained or even exceeded, and that the loaded crystal will also grow and lift its load. This condition was attained experimentally without difficulty in the observations recorded in this paper. If concentration increases still more rapidly, and exceeds the ability of both unloaded and loaded crystals to take up, through their continued growth, all the matter in excess of the saturation concentration, then additional nuclei may form upon which excess matter may be deposited. This appears to have been the condition attained in the last series of Bruhns and Mecklenburg's observations, in which the solution was evaporated to dryness.

Here six disks of porcelain loaded with weights were all raised a millimeter or more in the same solution, but Bruhns and Mecklenburg attribute this result to the action of capillarity and adsorption, and deny the competence of the "linear force of growing crystals" to effect such mechanical displacements.

A simple analysis suffices to show that capillarity in a solution evaporating to dryness can have no other effect than to press the crystal down upon its base with a force equal to $2TV/d^2$, where T is the surface tension, V the volume of the drop of liquid between the crystal and its base, and d the distance separating the two, and that the lifting action observed by Bruhns and Mecklenburg has occurred in spite of this opposing force and not because of it. Adsorption delays diffusion and diminishes the rate of growth, but does nothing to promote it. These forces therefore can not be appealed to in explanation of the lifting observed by Bruhns and Mecklenburg and by us.

We therefore return to the original thesis that the growth of crystals in saturated solution develops a linear force in the direction of the load, and that neither the magnitude of the load (up to the breaking load) nor its character (whether exclusively crystal substance or partly foreign substance) has any other effect than to increase solubility and so to raise the concentration necessary for potential supersaturation and growth upon the loaded crystals. This degree of supersaturation is readily attainable through evaporation or otherwise, and when attained the loads are lifted. With this thesis established there is no conflict between the observations of Bruhns and Mecklenburg and our own, and all the experimental evidence offered is perfectly correlated.

(18) Bemerkungen über die lineare Kraft wachsender Kristalle. George F. Becker und Arthur L. Day. Centralbl. f. Min, No. 14–15 (1916).

A German translation of "Note on the linear force of growing crystals" (J. Geol., 24, 313–33, 1916). Reviewed under No. 17 above.

(19) Crystals and crystal forces. Fred E. Wright. J. Wash. Acad. Sci., 6, 326–332 (1916).

In this paper the general problem of the measurement of crystal forces is stated and an outline is given of the possible modes of attack for its solution. A crystal is a body whose component atoms are arranged in definite space lattices; this arrangement is probably the result of the vectorial action of interatomic forces. These forces are spacially vectorial in character; but little is known of their order of magnitude and of the law of their variation with distance. They find expression in the development of crystal forms, in the rate and character of crystal growth, in the field of atomic forces, in the influence which they exert on other systems of forces, such as light-waves. The effects produced by a crystal on such a system of forces under different conditions of pressure and temperature can be measured and thus the law of

the variation of the one with the other be ascertained; in other words, a differential equation which, if it can be integrated, should furnish the desired crystal force-function.

The persistence of certain crystal configurations in spite of thermodynamic tendencies toward other more stable relations is well shown in rocks. The most remarkable fact in petrology is the relatively few rock-making minerals, especially in igneous rocks. These few minerals persist the world over and constitute the major part of the rocks of the earth's crust. This persistency of a few mineral species, notwithstanding great diversity in conditions of formation and in chemical composition, is fundamental, and indicates that the dominating factor in the crystallization of a magma is the stability of certain crystal types or configurations, and that these assert themselves, notwithstanding tendencies toward other groupings which thermodynamically are more stable. The study of crystals from the viewpoint of crystal forces is an integral part of geophysical and geochemical research.

(20) Note on the lithophysæ in a specimen of obsidian from California. F. E. Wright. J. Wash. Acad. Sci., 6, 367–369 (1916).

A brief description is given of the obsidian and its lithophysæ from Little Lake, about 40 miles south of Owen's Lake, Inyo County, California. The lithophysæ are similar in composition and appearance to the lithophysæ in the obsidian from Hrafntinnuhryggur, Iceland. A detailed study of both these occurrences has led to the conclusion that in the formation of the lithophysal cavities volatile gases set free during the crystallization of the spherulites were the active factor (causing not only the cavity but also the recrystallization), and not a secondary phenomenon accompanying the opening of the cavities by hydrostatic tension.

(21) Recent improvements in the petrograpic microscope. F. E. Wright. J. Wash. Acad. Sci. 6, 465–471 (1916).

During the past five years improvements have been introduced on the writer's petrographic microscope, either to increase the degree of precision of the measurements or to facilitate the use of the microscope by means of time-saving devices. The most important of these devices are:

(1) *Sliding objective changer.*—This has been substituted for the ordinary objective clamps which experience has shown to be unsatisfactory for rapid, accurate work. The new objective changer consists of a brass slider in which are mounted two objectives in eccentric, conical steel rings adjusted so that there is no change of focus or centering in passing from one objective to the second. The slider has wide bearing-surfaces and runs in a holder which is rigidly attached to the microscope.

(2) *The removal of astigmatism introduced by the analyzer.*—Siegfried Becher has shown that a telecentric arrangement of the lens system of the microscope, such that the rays pass through the analyzer as parallel beams, reduces to a large extent the astigmatic errors introduced by the analyzer. The practical application of this idea has been accomplished on the writer's microscope, following a suggestion by Dr. H. Kellner, by means of a weak negative lens below the analyzer and a weak positive lens above, the focal lengths of the lenses so taken that the rays from the objective pass through the analyzer as parallel beams and are then brought to the original convergence by means of the positive cap lens. For the removal of astigmatism in the interference figures a positive lens below the analyzer is required as well as the positive cap lens. These new lens systems are so arranged on the writer's microscope that the passage from one to the other is accomplished directly without appreciable loss of time.

(3) *The prism method for the observation of interference figures.*—A small doubly reflecting prism of special shape is introduced in a sliding carriage directly beneath the eyepiece and serves in the examination of interference figures by the Lasaulx method. Its use obviates the necessity of removing the eyepiece each time an interference figure is observed. Its small size, moreover, functions as a diaphragm and enables the observer to examine the interference figure from a single small mineral grain.

(4) *A device for use in the accurate measurement of extinction angles.*—An extension-arm with a needle at its outer end is attached to the microscope-stage. Settings on maximum darkness of a given mineral plate between crossed nicols are recorded by pressing down the needle-point into a piece of coordinate paper. The settings are made rapidly and are free from the personal element which is introduced when angular readings are taken. After a certain number of settings have been made with clockwise and counter-clockwise rotation of the stage the eye can estimate the average center of a series of points with sufficient accuracy for practical purposes and the angular reading of this center may then be taken.

(22) The petrographic microscope in analysis. Fred. E. Wright. J. Am. Chem. Soc., 38, 1647–1658 (1916).

In this paper the function of the petrographic microscope as applied to certain classes of problems of a chemical nature is discussed in a general way and its usefulness in such work is emphasized. Attention is directed to the difference between the ordinary microscope, which is only a magnifier, and the petrographic microscope, which, in addition, serves for the determination of the optical properties of minute crystal grains and plates measuring at least 0.01 mm. in diameter. The several optical properties thus used in diagnostic work are described briefly and the mode of their determination by means of the petrographic microscope is indicated.

(23) Some reactions involved in secondary copper-sulphide enrichment. E. G. Zies, E. T. Allen (Chemical Study), and H. E. Merwin (Microscopic Study). Econ. Geol., 11, 407–503 (1916).

(1) The reactions of a number of natural sulphides with copper-sulphate solutions have been quantitatively investigated. Attention has been confined to the following: chalcocite (Cu_2S), covellite (CuS), bornite (Cu_5FeS_4), chalcopyrite ($CuFeS_2$), pyrrhotite ($FeS(S)_x$), pyrite (FeS_2), sphalerite (ZnS), and galena (PbS). In all cases a copper-enrichment product is formed, either a sulphide which varies with the conditions, or as a special case, metallic copper and cuprite. In all cases the sulphate of the metal contained in the original sulphide is also formed, and usually sulphuric acid as well. This acid is derived from the oxidation of the sulphur in the sulphide by cupric sulphate. In these reactions cupric sulphate plays the rôle of an oxidizing agent, not only at elevated temperatures, but at lower temperatures as well.

(2) The sulphide-enrichment products are crystalline and all adhere firmly to the altered sulphide as in nature. When cupric sulphate is the enriching agent, *pyrite* alters to covellite and chalcocite. It has been shown that the alteration to chalcocite is represented by the following equation:

$$5FeS_2+14CuSO_4+12H_2O=7Cu_2S+5FeSO_4+12H_2SO_4$$

and that in the alteration to covellite the following equation in all probability represents the reaction

$$4FeS_2+7CuSO_4+4H_2O=7CuS+4FeSO_4+4H_2SO_4$$

The evidence is good that this reaction is involved when pyrite alters to chalcocite. *Pyrrhotite* alters to chalcopyrite and very probably to bornite.

The reaction can not at present be satisfactorily worked out on a quantitative basis owing to the fact that pyrrhotite varies in composition and is attacked by one of the reaction products, namely, sulphuric acid. *Chalcopyrite* alters to covellite and chalcocite. The reaction between chalcopyrite and cupric sulphate to form chalcocite has been shown to be represented by the equation

$$5CuFeS_2+11CuSO_4+8H_2O=8Cu_2S+5FeSO_4+8H_2SO_4$$

When chalcopyrite alters to covellite the experiments point strongly to the reaction represented by the following equation:

$$CuFeS_2+CuSO_4=2CuS+FeSO_4$$

and also indicate that this reaction is involved in the alteration to chalcocite. *Bornite* alters to chalcocite as follows:

$$5Cu_5FeS_4+11CuSO_4+8H_2O=18Cu_2S+5FeSO_4+8H_2SO_4$$

It has also been shown that bornite may alter to covellite and chalcocite thus:

$$Cu_5FeS_4+CuSO_4=2Cu_2S+2CuS+FeSO_4$$

Covellite alters to chalcocite as follows:

$$5CuS+3CuSO_4+4H_2O=4Cu_2S+4H_2SO_4$$

The experiments also furnish evidence that this reaction proceeds in two stages, thus:

$$CuS+7CuSO_4+4H_2O=4Cu_2SO_4+4H_2SO_4$$
$$4CuS+4Cu_2SO_4=4Cu_2S+4CuSO_4$$

It is very probable that the latter reaction is involved when these sulphides alter to chalcocite and when cupric sulphate is the enriching agent. *Sphalerite* and *galena* alter first to covellite and subsequently to chalcocite:

$$ZnS+CuSO_4=CuS+ZnSO_4$$
$$5CuS+3CuSO_4+4H_2O=4Cu_2S+4H_2SO_4$$

$$PbS+CuSO_4=CuS+PbSO_4$$
$$5CuS+3CuSO_4+4H_2O=4CuS+4H_2SO_4$$

(3) The order of stability of the sulphide enrichment products toward cupric-sulphate solutions is: chalcopyrite, covellite, chalcocite; each of them changing into the succeeding sulphide by the further action of cupric sulphate. Chalcocite is by far the most stable sulphide of all, under these conditions, but it may finally be converted into metallic copper and sulphuric acid, *though very slowly indeed even at 200°*. The most favorable conditions which have been observed for the formation of the intermediate products, chalcopyrite and covellite, are the exposure of a large surface of the reacting sulphide to the action of a comparatively dilute solution of copper sulphate.

(4) All these reactions have been studied at several temperatures ranging from 200° down to 30°. In the main the *rate* rather than the *nature* of the reaction is changed by raising the temperature, but there are a number of secondary reactions, slight or negligible at low temperatures, which become pronounced at higher temperatures. Thus ferrous sulphate is partly changed into ferric sulphate by cupric sulphate:

$$2CuSO_4+2FeSO_4 \rightleftarrows Cu_2SO_4+Fe_2(SO_4)_3.$$

At elevated temperatures, hydrolysis generally conditions the formation of considerable hematite, cuprite, and metallic copper from the two primary products of the above reaction. To what extent the metallic copper and cuprite sometimes found in the natural enrichment zone are derived from the hydrolysis of cuprous sulphate is not clear from these experiments.

(5) The results of qualitative experiments indicate that enrichment proceeds faster in the presence of cuprous sulphate than in the presence of cupric sulphate.

(6) The influence of sulphuric acid on the enrichment reactions has been studied. The enrichment of chalcopyrite and pyrite in our experiments has been retarded by an increase in the concentration of sulphuric acid. The explanation for this is found in the fact that hydrolysis of the ferric sulphate, formed as we have stated above (paragraph 4), is either hindered or prevented, and thus the influence of the cuprous sulphate formed from cupric sulphate by the reducing action of ferrous sulphate is held back. The result is that the formation of cuprous sulphate is limited, and since the rate of reaction of cuprous sulphate on the sulphide is much faster than that of cupric sulphate, enrichment itself is retarded. The enrichment of galena, sphalerite, pyrrhotite, and bornite is accelerated by sulphuric acid, for the "solubility" of these sulphides is thus materially increased. Chalcopyrite is one of the products at higher temperatures between bornite and 2 per cent sulphuric acid alone.

(7) The influence of ferrous sulphate on the enrichment reactions has also been studied to some extent. The first effect is to increase the rate by increasing the quantity of cuprous sulphate in solution, and cuprous sulphate is more rapid than cupric in its action on the sulphides. However, the effect is soon lost unless the ferric iron formed is removed from the solution.

It may be stated here that a reversal of the principal enrichment reactions, such for example as

$$5FeS_2+14CuSO_4+12H_2O=7Cu_2S+5FeSO_3+12H_2SO_4$$

has not been reproduced experimentally. The attempt to introduce iron into bornite by allowing the sulphide to react with ferrous sulphate alone has not met with success.

(24) Preliminary report on the system, lime: ferric oxide. R. B. Sosman and H. E. Merwin. J. Wash. Acad. Sci., 6, 532-537 (1916).

The melting-point diagram of this system was worked out by means of thermal curves and optical examinations on mixtures of Fe_2O_3 and CaO, heated in platinum crucibles in air. Near the Fe_2O_3 side of the diagram too much ferrous iron is formed by dissociation at temperatures above 1250° to permit of the determination of the melting temperatures except under pressures of oxygen greater than atmospheric. Two compounds are formed between CaO and Fe_2O_3, namely, $2CaO.Fe_2O_3$ and $CaO.Fe_2O_3$. Both appear to be dissociated at their melting-points. The compound $2CaO.Fe_2O_3$ dissociates with partial fusion at 1436°, and the compound $CaO.Fe_2O_3$ likewise at 1216°. There is a eutectic at 1203° between $CaO.Fe_2O_3$ and Fe_2O_3. Optical properties were measured by means of a new immersion medium, consisting of an amorphous mixture of selenium and arsenic selenide.

(25) The chemistry of portland cement. G. A. Rankin. Address delivered at the Twelfth Annual Convention of the American Concrete Institute, Chicago, Feb. 14-17 (1916). (Published by the Institute.)

A presentation of the chemical problem which confronts the portland-cement manufacturer, considered in the light of recent studies of lime, alumina, and silica. See "The ternary system $CaO-Al_2O_3-SiO_2$," Rankin and Wright, Am. J. Sci. (4), 39, 1-79, 1915, reviewed in Year Book 13, page 155, (1914) and "The constituents of portland-cement clinker," J. Ind. Eng. Chem., 7, 466, 1915, reviewed in Year Book 14, page 165 (1915).

(26) The chemistry of portland cement. G. A. Rankin. Concrete (Cement Mill Section) 8, 15-20 (1916).

Reprinted from "The chemistry of portland cement" (Address delivered at the Twelfth Annual Convention of the American Concrete Institute, Chicago, February 14–17, 1916). Reviewed under No. 25 above.

(27) The chemistry of portland cement. G. A. Rankin. Cement Era, 14, 79–83 (1916).

Reprinted from "The Chemistry of portland cement" (Address delivered at the Twelfth Annual Convention of the American Concrete Institute, Chicago, February 14–17, 1916). Reviewed under No. 25 above.

(28) Portland cement. G. A. Rankin. J. Franklin Inst., 747–784 (1916).

An address given at the Franklin Institute, Philadelphia, embodying most of the results of the investigation of the relations between lime, alumina, and silica in portland-cement clinker, which was first published under the title "The constituents of portland-cement clinker" (J. Ind. Eng. Chem., 7, 466, 1915), and reviewed on page 165 of Year Book No. 14 (1915). Some interesting applications of these conclusions to the development of portland cement are pointed out.

(29) Chemical analyses of igneous rocks, published from 1884 to 1913, with a critical discussion of the character and use of analyses. H. S. Washington. U. S. Geol. Survey, Professional Paper 99, 1,200 pages (1916).

This is a revision and expansion of Professional Paper 14, published in 1903. The text is devoted to discussions of the importance of chemical analyses in the study of igneous rocks; the general characters of rock analyses, referred especially to their accuracy and completeness; the possible sources of error involved in making them; the method adopted of "rating" them, that is, determining their relative worth for use; remarks on several features of the tables; and a list of the publications consulted, with some minor matters.

The tables are divided into four parts: I, superior analyses of fresh rocks; II, incomplete, but otherwise superior, analyses of fresh rocks; III, analyses of weathered rocks and of tuffs; IV, inferior analyses.

The total number of analyses amounts to about 9,500, while the earlier edition embraced 2,881. The search for analyses throughout the literature has been very thorough, chiefly based on the Library of the U. S. Geological Survey, and it is believed that the collection is practically complete for those which have been published between 1884 and 1913, both inclusive, with the addition of many hitherto unpublished analyses contributed by petrographers and official surveys of many countries.

The analyses in Part I (which are all of superior quality and therefore the most useful) number about 4,950. The "norm" of each has been calculated by the author, and these analyses are arranged according to the quantitative system of classification. The analyses in the other parts are arranged according to the usual system.

It may be added that all the original cards on which the analyses were collected are preserved and on file in the Geophysical Laboratory. It is purposed to arrange them geographically, and to use them, in conjunction with the published work, in studies of the distribution of rocks over the earth, the characters of petrographic provinces, and other subjects.

(30) The common refractory oxides. Robert B. Sosman. J. Ind. Eng. Chem., 8, 985–990, (1916).

Some of the properties of the individual oxides are compared and a graphical summary is given of all the possible two- and three-component systems of SiO_2, Al_2O_3, MgO, CaO, FeO, and Fe_2O_3. The binary compounds are in most cases made up of the individual oxides in simple proportions, usually 1:1 or

2:1. The ternary compounds are likewise made up of the simpler binary compounds in simple proportions. The impression given by a general review of the silicates and other compounds of the refractory oxides is that these compounds are of the so-called "molecular" class. Little is to be expected, therefore, from structural formulas for the silicates until the nature of the chemical union in "molecular" compounds is better understood. The bearing of the X-ray analysis of crystal structure upon the problem is shown, and it is suggested that certain of the more complex crystalline compounds may be geometrical rather than chemical products. Various examples of the practical aspects of the properties discussed are added.

(31) A precision projection plot. Fred. E. Wright. J. Wash. Acad. Sci., 6, 521–524 (1916).

For the graphical solution of spherical triangles and of certain crystallographic-optical problems a projection of the sphere, such as the stereographic, is commonly used. Chauvenet in 1854 published such a stereographic projection plot; in 1885 Sigsbee prepared an exceedingly exact stereographic projection plot and recommended that the solution be made by means of tracing-paper placed over the accurate base-plot. In 1902 Wulff proposed the same procedure as a new method, which is now known under his name. The method should, however, be called the Chauvenet-Sigsbee method. The precision plot described in this paper is simply a mechanical device for rotating a piece of tracing-paper over an accurate projection-base printed on thick celluloid. A metal stand supports an electric light which illuminates a disk of frosted plate-glass; this plate in turn supports the equatorial projection-net which can be accurately centered to the axis of rotation of an outer steel ring which runs in an accurately turned bearing and carries the tracing-paper on which the measurements are plotted in the positions indicated by the underlying projection-base. The tracing-paper is held in place by means of hinged iron bars which pass over the outside square ends of the rotating ring and clamp the paper securely.

(32) The lava eruption of Stromboli, summer-autumn, 1915. F. A. Perret. Am. J. Sci. (4), 42, 443–463 (1916).

This paper describes one of the most violent eruptions of Stromboli that has been recorded, and one which is especially noteworthy because of the almost continuous emission of lava down the Sciarra during a period of about 5 months—the emission of lava being a rare phenomenon at this volcano, where the activity is normally of the explosive type.

The record of observed phenomena is based upon personal observations from November 9 to November 30, 1915, supplemented by notes made during the preceding months by an Italian official on the island. Four vents were active, three being on the upper edge of the Sciarra and the other farther back on the terrace. The lava issued from a tunnel-like opening close to one of the permanent explosive vents (A), near the center of the upper part of the Sciarra, and at times it flowed in a continuous stream to the sea. A remarkable feature of its entrance into the sea was the absence of commotion whenever the lava flow was still incandescent on entering the water. This phenomenon, also observed at Sakurashima, is attributed to the formation of a protective, thin, poorly conducting, and quasi-flexible lava sheath through the sudden chilling. Chemical analyses show that this lava is a basalt, and closely resembles in composition those of previous eruptions.

Observations were made of the changes in the volume of visible vapor (the "smoke" cloud) above the vents concomitant with the hygroscopic state of the air—a change from a dry to a damp atmosphere immediately resulting in a great increase in the amount of the volcanic "cloud," without any cor-

responding change in the state of volcanic activity within the craters. This is attributed to atmospheric condensation due to the volcanic dust.

In contrast with previous eruptions, explosive phenomena were not conspicuous features, though two violent explosions were recorded. This is in accord with an opinion already expressed elsewhere, that Stromboli has recently entered on a new period of increased activity of a kind different from that which has been observed at Stromboli hitherto, and one which should therefore be most carefully and if possible continuously studied.

(33) On the measurement of temperature in bore-holes. John Johnston and L. H. Adams. Econ. Geol., 11, 741–762 (1916).

A systematic and accurate investigation of temperature gradients within bore-holes is desirable because it would yield information as to the relative heat conductivity of different strata, and there is also reason to believe that it would be of some economic importance. Such an investigation would, however, be of little use unless the accuracy of the observations were better than has hitherto been customary. In this paper the various methods which may be used for the measurement of temperatures in bore-holes are discussed in detail and some of the precautions which must be observed are pointed out. The electrical-resistance thermometer is recommended as the most satisfactory device for such temperature measurements, and some new results obtained with a resistance thermometer are presented. It appears that the mercury thermometer can not yield results with an uncertainty less than $\pm 0.1°$ C., that it is not absolutely trustworthy unless the temperatures to be measured are higher than the prevailing air-temperature at the surface, and that the attainment of even this accuracy requires an exposure of more than an hour at each horizon. In comparison with this, the accuracy of the electrical thermometer is ten times as good, and the time required for an observation is not over one-third as long; the necessary apparatus is, however, somewhat less easily portable and its operation requires some degree of previous experience with electrical measurements.

(34) The rôle of inorganic agencies in the deposition of calcium carbonate. John Johnston and E. D. Williamson. J. Geol., 24, 729–750 (1916).

Though organic agencies are predominantly responsible for the deposition of calcium carbonate, yet the purely inorganic factors should also be taken into account in discussions of the mode of deposition. In this paper emphasis has been laid on one point which has not received adequate recognition, namely, the concentration of calcium relative to the limiting saturation concentration of calcium carbonate under the particular conditions, or in other words, the relative degree of saturation with respect to calcium carbonate in the ocean. The importance of this factor is obvious if we recollect that the chance of a permanent deposit is, *ceteris paribus*, greater the more nearly saturated the surrounding water is; its neglect is doubtless due to the erroneous and misleading statements as to the solubility of $CaCO_3$ which have been prevalent. The solubility under specified conditions can now be calculated with the requisite accuracy; it is affected materially by variations of temperature and of concentration of free CO_2 such as occur in nature. For example, a change in the proportion of CO_2 in the adjacent air from 3.2 to 3.0 parts per 10,000, or an increase of temperature of 2° C. would result ultimately in the precipitation of about 2 grams $CaCO_3$ from every cubic meter of a solution saturated with it. Comparison of the solubility as calculated with the available analytical data indicates that the warmer surface layers of the sea are substantially saturated with respect to calcite, and, consequently, that precipitation is to be expected wherever the water is being warmed, or is losing CO_2, or both, and

this independently of any other agencies. Indeed, these inorganic factors must be considered, no matter what be the agency inducing precipitation; for example, there is ground for believing that calcareous organisms are more abundant the more nearly saturated with $CaCO_3$ the water is. The view, here advocated, that a somewhat greater rôle be assigned to the inorganic factors than has hitherto been usual, does not conflict with other views—it merely shifts the emphasis a little; nor does it conflict with any facts that have been definitely ascertained. Its precise importance can be determined only by accurate determination of temperature, salinity, and, particularly, of concentration of CO_2—free and total—of the water, carried out systematically over the ocean; the results of such an investigation, properly carried out, would have an important bearing on many outstanding biological as well as geological problems.

(35) An apparent correspondence between the chemistry of igneous magmas and of organic metabolism. H. S. Washington. Proc. Nat. Acad. Sci., 2, 623–626 (1916).

It has been shown that in igneous rock magmas and in minerals magnesium and potassium on the one hand, and iron and sodium on the other, tend to vary together. It is pointed out in this paper that, seemingly, the same relations hold true in the organic world, iron and sodium being essential to the metabolism of animal life and magnesium and potassium to that of vegetable life. This is indicated by the following facts: Hemoglobin and its derivatives (essential to the higher animals in the oxidation processes) are iron compounds; and sodium, rather than potassium, is an essential constituent of the blood plasma, while potassium is relatively toxic. On the other hand, chlorophyll, which is chemically closely allied to hemoglobin, and which is the agent by which most plant life assimilates CO_2 from the air, is a magnesium compound, and at the same time potassium is essential to plant life, while iron and sodium are relatively toxic.

This congruity of these two pairs of elements, both in the mineral and organic worlds, may be simply fortuitous, but it is suggested that it probably depends on fundamental chemical relations, as yet unknown.

DEPARTMENT OF HISTORICAL RESEARCH.*

J. Franklin Jameson, Director.

The following report, the eleventh annual report of the present Director, covers the period from November 1, 1915, to October 31, 1916. The regular staff of the Department has continued without change during the year. During several months of the year the Department had the aid, at first for a portion of the time, but afterward continuously, of Dr. James A. Robertson, librarian of the Philippine Library at Manila, who rendered valuable services in connection with the preparation of the proposed Atlas of the Historical Geography of the United States.

The Department has continued to occupy the same quarters as in preceding years, in the Woodward Building in Washington. During the summer months, in accordance with its usual custom, the Director and a portion of the staff worked at its summer headquarters in North Edgecomb, Maine, while several other members of the staff worked at the library of Harvard University, where most gratifying privileges were accorded to them, and some in Washington, where, it can not be too often emphasized in these reports, the Library of Congress, with the greatest liberality, affords the Department every facility and opportunity that could be desired. Special acknowledgments should be made of the constant kindness of Dr. Gaillard Hunt, chief of the Division of Manuscripts, and Mr. P. Lee Phillips, chief of the Map Division, as well as of the Librarian of Congress, Dr. Herbert Putnam.

The main purpose of the Department, as set forth in former reports, is, briefly expressed, to serve the interests of present and future makers of historical monographs and general histories, by providing aids belonging to one or the other of two main classes—either books which show the inquirer the existence and location, or assist him in the use, of bodies of historical sources, or books which themselves present in proper scientific form the full text of important historical materials. Thus the publications of the Department fall naturally in two classes, the one that of reports, aids, and guides, the other that of textual publications of documents. It has been customary in these annual reports to consider, successively, first the work of the past year, in respect to each of these two classes of publications and in respect to the miscellaneous activities of the Department, and then the plans for the ensuing year, under the same three headings.

*Address: 1140 Woodward Building, Washington, D. C.

WORK OF THE PAST YEAR.

REPORTS, AIDS, AND GUIDES.

In June the Institution published for the Department a Guide to the Materials for American History in the Archives of Switzerland and Austria, in which the main portions, relating to the archives of the German cantons of Switzerland, and to those of Austria, were prepared by Professor Albert B. Faust, of Cornell University, after a careful examination of those archives extending through several months in 1913, while the portion relating to the archives of the French cantons of Switzerland rests upon investigations made by the Director of the Department. The volume is one of 299 pages and has a full index. It describes the archives and what they contain for American history with fulness of detail, and in the manner deemed most useful to students of that history. Swiss and Austrian emigration to America, in both the eighteenth and nineteenth centuries, having formed a highly important element in the German movement toward America, and having contributed a large element to our German-American population, it is expected that students of that movement will find the book valuable, and indeed reviews of it already published have testified to such esteem. Mr. Faust has himself presented to the public some of the chief results that may be derived from the data discovered by him, through a valuable article in the *American Historical Review* for October 1916, entitled "Swiss Emigration to the United States in the Eighteenth Century," and accompanied by a body of interesting documents from the Swiss archives printed *in extenso*. Genealogical societies interested in the early Germans in America have manifested interest in his discoveries from another point of view.

As the year reported upon is coming to its end, the Institution is on the point of publishing, in a volume of 594 pages, a Descriptive Catalogue of the materials for United States history in that section of the Archives of the Indies, at Seville, which is called "Papeles procedentes de la Isla de Cuba," prepared by Mr. Roscoe R. Hill, now professor of history in the University of New Mexico. The text of this book, planned by Mr. Hill at the beginning of his labors to consist of 500 pages, and actually consisting of almost exactly that number, takes up in numerical order the 934 *legajos*, or bundles, in this section of the Archives of the Indies, relating to the history of the United States, chiefly in the period between 1763 and 1819, and gives a methodical description of each. This description, averaging about half a page of print in the case of each *legajo*, gives in full the title or designation borne by the *legajo*, its size, and the number of documents which it contains, exact information concerning the dates which it covers and the distribution of the papers within those dates, a general description of its organization, or subdivisions, with statements as to writers and persons addressed and as to the main subjects touched upon, and

an enumeration, with titles when necessary, of the most important documents in each bundle. The text, therefore, furnishes general guidance to a collection of papers numbering between 400,000 and 500,000 and, upon a conservative estimate, makes particular or individual mention of not less than 10,000 of the most important among them. An elaborate index, prepared by Mr. David M. Matteson, of Cambridge, Massachusetts, noted for the preparation of many excellent indexes to historical books, extends to nearly 100 pages of print, and makes the whole mass of material readily available to the inquirer. The "Papeles procedentes de la Isla de Cuba" constitute the main mass of material for the history of Spanish Louisiana and of Florida in the period named, and it is safe to say that this volume alone, if due use is made of it by students, is capable of placing that whole history upon a new basis. On the one hand, the main concerns of provincial administration are fully covered by documents of the first rank, such as the correspondence between the provincial governors and their superiors in office, the Captains General at Havana and the ministers in Spain, while on the other hand the local history of places in the region at which the Spaniards had even the smallest posts can be followed through the aid of the documents left by the officials of that Government, than whom few administrative officials in the world's history have made a more unwearied use of the pen.

In the last annual report mention was made of a fuller guide to the same material, retained for the present in manuscript, namely, a calendar which Mr. Hill had caused to be made of about 143 *legajos* selected as the most important and embracing itemized descriptions of some 58,000 documents. This calendar had been made by him and his clerical assistants at Seville, in duplicate, on two sets of slips. The process of arranging one of these sets of nearly 60,000 slips in chronological order has been begun. It is expected that by means of this set the Department will be able to locate promptly in the Archives, for the benefit of any historical inquirer, any important paper in the collection. The other set remains arranged by *legajos*, in the order in which the documents themselves are found.

During the year the photographers acting for the Department, Srs. Hijos de Pérez Romero, in Seville, and the photographic printer Mr. L. Doysié of Paris, have completed the set of photographs, embracing 3,000 plates, intended to cover the main series of regular official (civil) despatches, found in the Papeles procedentes de la Isla de Cuba, addressed by Spanish governors in Louisiana to the Captain General at Havana, and extending from the arrival of Ulloa as governor in 1765 to that of Carondelet at the beginning of 1792. Mrs. Adolph Bandelier, to whom the Department is much indebted for supervision of the work during its progress in Seville, carried out after her return to America the making of a calendar of each of these despatches, copies of which can serve as tables of contents to the collection, and as guides to

its use in any library which may purchase a series of the photographs. Ten prints have been made from each negative, and ten series of photographs are available for purchase by institutions or individuals in America. The series is arranged in chronological order, and presents remarkably few gaps. Sets will be sold at the cost of the photographic work and printing.

Professor Frank A. Golder's Guide to the Materials for American History in the Archives of Russia now stands entirely ready in proof, and will be issued as soon as the index, finished in manuscript, can be printed and the volumes bound. It constitutes a volume of 177 pages, treating in methodical order the American contents of each of the many archives in Petrograd and Moscow. The documents for American history in these archives, it should be pointed out, while in some cases available only to those who read Russian, are in at least as many instances written in French. This is especially true of the documents in the archives of the Ministry of Foreign Affairs, which illustrate in the fullest manner the diplomatic relations, highly important at several periods, between Russia and the United States. These papers Mr. Golder was permitted to examine down to 1854, while in several other ministries, notably that of Marine, his permissions extended much farther. Naturally, the two chief matters of American history upon which light may be obtained from the Russian archives are the mutual diplomatic relations between the two governments, and the history of Russian America. Upon the latter subject, while the archives of the Russian American Company have in the main disappeared, there is in various archives a great amount of valuable material, covering the whole history of Russian expansion in the Pacific from the times of Bering till the cession of Russian America to the United States in 1867. As the development of the Pacific coast comes to its true place in the history of the United States, such materials as Mr. Golder has discovered and noted will be rightly appreciated. It is proper to acknowledge the generous aid, in the revision of a portion of the manuscript, received from Professor Alexander Lappo-Danilevskii, of the Petrograd Academy of Sciences.

Mr. Leland has devoted a large part of the year to working over the notes which he took during his various expeditions to Paris, to serve as a basis for a guide to the manuscript materials for American history in the archives and libraries of that city. The work, it will be remembered, was interrupted by the advent of the war and the closing of certain archives, at a time when small but significant portions of several of them still remained to be covered. Those notes which Mr. Leland has nearly ready for the press are those relating to certain materials in the Foreign Office, the Ministry of the Colonies, and the Archives Nationales. During the latter part of the year, however, it has been decided that a volume on the historical manuscripts relating to America in the Parisian libraries can be prepared for publication, even

should Mr. Leland not be able to return to Paris during the coming year. Consequently he is at present engaged in preparing for the press that portion of his report which deals with the Bibliothèque Nationale. This will be accompanied by reports on materials in other libraries of Paris, notably that of the Arsenal, the Mazarine, the Ste. Geneviève, that of the Chamber of Deputies, and other similar libraries. The whole will constitute a considerable volume, of which students can make profitable use without waiting for the completion of the volumes on the archives.

Work on the Atlas of the Historical Geography of the United States has been prosecuted chiefly in the Map Division of the Library of Congress, where aid of the greatest value has been most obligingly supplied by Mr. P. Lee Phillips, chief of that division. The work of Dr. Paullin, who has principal charge of the enterprise, has consisted chiefly in the elaboration of the maps, and of the accompanying letter-press, illustrating the history of the boundary controversies of the United States from 1776 to the present time. This large piece of work has been nearly completed. It has involved prolonged historical research, and the construction of many ingeniously devised maps. In November 1915, in order that the most expert advice upon the problems involved might be obtained at the beginning of the work, a special conference was called, in which the following gentlemen, invited by reason of special acquirements bearing upon the problems from different points of view, obligingly took part: Dr. Otto H. Tittmann, for many years chief of the United States Coast and Geodetic Survey; Mr. John E. McGrath, of that establishment; Mr. James White, formerly geographer of the Dominion of Canada and editor of its official atlas; and Dr. Jesse S. Reeves, Professor of International Law and of the History of Diplomacy in the University of Michigan. The conference continued for a week, Dr. Tittmann kindly serving as chairman, Dr. Paullin as secretary. The Department would wish to make public expression of its gratitude to these accomplished gentlemen. Their friendly and in a sense international discussions were of great interest, and resulted in many valuable suggestions toward the work in hand.

Besides the completion of this section of the Atlas by Dr. Paullin, assisted by Mr. J. B. Bronson, of the Navy Department, as draftsman, the Department availed itself of the presence of Dr. James A. Robertson in Washington to carry through its preliminary stage the preparation of another important section of the Atlas. This was the section devoted to reproductions of old maps, as a means of exhibiting the progress of geographical knowledge respecting America, the progressive opening up of the continent by European, and later by American, explorers. Dr. Robertson, whose acquirements in the field of cartographical history are well known, spent several months in a careful survey of all the material available for his purpose in the Library of Congress, and also visited certain collections in New York, where he

was most kindly aided by Dr. Edward L. Stevenson, librarian of the Hispanic Society of America; by Dr. Isaiah Bowman, of the American Geographical Society, and others. His report, rendered at the end of the year, presents a comprehensive and ingenious scheme whereby, within a moderate compass of about 34 plates, what is essential in the cartographical history of America can be exhibited in photo-lithographic facsimile, without attempting, as it would be out of scale to attempt, such elaboration of the theme as has been, in certain portions of the field, carried out by Dr. Stevenson himself, in the Atlas specially devoted to this division of it which he has prepared. Dr. Robertson has also composed, in at least a preliminary draft, a large part of the letter-press which should accompany the maps proposed by him for inclusion in this portion of our Atlas.

In August and September the Department was able to avail itself, for several weeks of his official vacation, of the services of Mr. Luis Marino Pérez, librarian of the House of Representatives of Cuba, and author of the Institution's "Guide to the Materials for American History in Cuban Archives." Mr. Pérez proceeded to Jamaica, having in hand a partial inventory of the archives of that island which had been prepared by Professor Charles H. Hull, of Cornell, during a visit to the island some years ago, and elaborated this inventory by further researches into a comprehensive report upon the archives of the colony. It is a pleasure to acknowledge the courtesies and facilities which he received from the governor of Jamaica and other authorities of the island, at the instance of His Excellency the British Ambassador in Washington.

TEXTUAL PUBLICATIONS OF DOCUMENTS.

The first volume of Dr. Davenport's collection of "Treaties between European Powers, relating to American History," extending to the treaties of 1648, has also received much benefit from Dr. Robertson's presence in Washington. He has obligingly read those portions of the text, relating to the earliest periods of American history, which lay within the field of his own special studies and has made valuable suggestions. The Director hopes soon to complete his own reading of the manuscript and to submit it for publication. Dr. Davenport, herself, has continued through the year the preparation of her second volume.

The volumes of "Letters of Delegates to the Continental Congress" have been slightly increased by the addition of letters which have come to light during the year. Dr. Burnett has completed the process of annotation to the end of March 1778.

The preparation of the series of "Proceedings and Debates of Parliament respecting North America from 1585 to 1783" consists naturally of two portions, the work on the proceedings of the English House of Lords, the English House of Commons, the Irish House of Lords, the Irish House of Commons, and the Scottish Parliament, and the work on the debates in these bodies. The selection and copying of materials

of the first sort, from the journals of these various bodies, has now been completed. The work on the debates has thus far been confined by Mr. Stock, editor of this series, to the debates of the English Lords and Commons. This portion of the work requires a greater amount of critical labor than that on the proceedings. The latter, though necessarily requiring much time, has consisted simply in finding, and in drawing off from the journals, the passages relating to America; but the debates, being unofficially reported, are presented in a variety of sources, and require the examination of varying reports of the same debates, the making of decisions as to their mutual relations and their varying degrees of authority, the selection and copying of texts, and the collecting of material for proper annotation. The selection of texts of debates has been finished to 1750, and the beginning of the work of copying them has been made. The remarkable record of debates in the Parliament of 1768–1774, kept by Henry Cavendish, M. P. (a Parliament otherwise but little reported), has been in large part copied from his manuscripts preserved among the Egerton manuscripts in the British Museum, Wright's printed version of certain parts, published in 1839–1843, having been found to differ widely and almost constantly from the original. Much of Cavendish's manuscript, in the parts which Wright did not reach, presents great difficulties of reading and interpretation, parts of it indeed being in a difficult short-hand; but it is believed that, with the aid of the copies of certain portions, and the photographs of others, which have been ordered, it will be possible to obtain from this source a considerable amount of additional material regarding the often important discussions of American affairs in this Parliament.

Miss Donnan, in portions of her time not occupied with editorial labors upon the *American Historical Review*, has been at work in the search for material upon the history of the African slave-trade, the sources and methods of supply, on which it seems possible to bring together an important collection of original material of great interest. Her search has extended through all narratives, found in the Library of Congress and in several other American libraries, of travelers, explorers, scientists, missionaries, sea-captains, captives, pirates, officers of the Royal African Company, and slaves, who spent any time on the west coast of Africa between the beginning of the fifteenth and the beginning of the nineteenth centuries.

MISCELLANEOUS OPERATIONS.

As heretofore, the editing of the *American Historical Review* has been carried on in the office of the Department and by its staff. Aid has been given in a number of ways to the American Historical Association, of which Mr. Leland is secretary, and to various other American historical societies and departments of history in the several States, for which investigations or other services could be performed in Wash-

ington. Besides the extensive series of copies of historical manuscripts which is being made in Paris for the Library of Congress under Mr. Leland's direction, Mr. Golder procured for the same institution a body of transcripts from Russian archives. As in previous years, searches and copies have been made, in Washington archives, by the Department, or under its supervision, for a considerable number of inquirers.

The Department has endeavored to do its part toward bringing about the erection, in Washington, of a suitable national archive building. At the conference of archivists held in Washington in December, at the time of the meeting of the American Historical Association, Mr. Leland and Mr. Stock made an effective exhibition, by lectures and slides, of the evil conditions now existing and of the remedies suggested by European example, in the form of archive buildings and devices. Their demonstration was repeated before the Pennsylvania History Club at Philadelphia and before the American Library Association at its annual meeting at Asbury Park, in June.

PLANS FOR 1917.

REPORTS, AIDS, AND GUIDES.

The first work of the Department in the year beginning November 1, 1916, should be the issue of Mr. Hill's Descriptive Catalogue (Seville) and of Mr. Golder's Guide to the Materials for American History in the Russian Archives. Mr. Leland will do all that can be done to finish, within the year, that volume of his Guide to the Parisian materials which concerns manuscripts in libraries. At some time after the conclusion of the present war, the collection of the last remaining data for his other volumes can be undertaken.

But for conditions incident to the war, the Department had hoped to send a scholar of high qualifications for the purpose, Professor Herbert C. Bell, of Bowdoin College, to make an examination of the archives of the British West Indies (exclusive of Jamaica, already covered by Mr. Pérez's researches), and to compile a report upon what they contain. This now seems inexpedient, but it is possible, while waiting, to prepare in London a portion of the same book, for the data to be collected in the West Indies would need to be supplemented by fuller details regarding the papers, relating to those islands, which are preserved among the Colonial Office papers in the Public Record Office at London. The materials in London and the materials in the islands are the necessary complements of each other. A volume so composed, presenting a detailed view of the historical materials in and relating to the British West Indies, would be of high value to all students of the Colonial and Revolutionary periods of American history; for the history of the mainland colonies can not possibly be rightly understood, except in connection with the island colonies associated with them in the same imperial system.

Dr. Paullin, with such appropriate assistance as can from time to time be invoked, will work upon the Atlas of the historical geography of the United States.

TEXTS.

The Department will expect to be permitted to bring out, during the year, the first volume of Miss Davenport's Treaties between European Powers, relating to American history, extending to 1648, while she proceeds toward the completion of the second volume, extending from that date to 1713.

Dr. Burnett will expend as large a part of his time as is possible upon the further annotation of his "Letters of Delegates to the Continental Congress." It has been concluded that the better course will be to bring out the volumes of this series as they are completed, without waiting for the completion of the whole work to the year 1789. Accordingly, Dr. Burnett's first task will be to put the finishing touches upon the first volume, which is expected to extend from the first assembling of the Continental Congress in September 1774, either to July 4, 1776, or to the end of that year.

Similarly, in the case of the series of "Proceedings and Debates of Parliament respecting North America," it has been resolved that the first volume shall be put into its final shape and offered for publication at once. This first volume will extend to some point in the early part of the eighteenth century. It will inevitably consist mainly of materials from the journals of Lords and Commons, debate material respecting America being relatively scanty in the seventeenth century. With this object in view, the manuscript material in the British Museum, needed for the purposes of the series, to 1750, will be procured in transcripts as early as possible in the year.

Miss Donnan will devote whatever time is not occupied with her duties in connection with the *American Historical Review* to further research in the history of the African slave-trade, relating especially to the sources and methods of supply.

MISCELLANEOUS OPERATIONS.

The Department will no doubt maintain, in 1917, activities similar to those which, under this heading, have been described above in that part of this report which relates to the last 12 months. It is confidently believed that the presence of Professor Frederick J. Turner, of Harvard University, as Research Associate, will stimulate all the work of the Department. It will certainly cause all those who are occupied in its activities to appreciate more vividly the relation of their work to that of historians and to the general progress of American historical study and literature.

DEPARTMENT OF MARINE BIOLOGY.*

ALFRED G. MAYER, DIRECTOR.

The abandonment of the United States naval base once maintained at Tortugas renders it practically imperative that we also abandon this region as a site for our principal laboratory; for despite its preeminent advantages in the purity of its ocean water, its isolation, so conducive to intensive research, and its fauna well supplied with forms required for the needs of a modern experimental laboratory, the expense of maintenance has become so great that another more available site must be selected in which to continue and expand our studies. The rising price of gasoline is a considerable factor in this regard, for our only means of communication with the world is through Key West, distant 68 miles, and thus our yacht the *Anton Dohrn* must make weekly trips to this base of supplies and back to Tortugas, drawing away her crew and depriving us of her services in such oceanographic work as she is well fitted to undertake.

It is therefore necessary that the best possible site for our new base be found and that the entire West Indian region be studied with a view to supplementing the studies which may be carried out at the main laboratory wherever situated. With this in view, the Director has already visited Jamaica, Porto Rico, St. Thomas, St. Croix, Guadeloupe, Martinique, Dominica, St. Lucia, Barbados, and Demerara, and during March and April 1916, accompanied by Dr. H. L. Clark, of the Museum of Comparative Zoology at Harvard University, and Dr. Theodor Mortensen, of Copenhagen University, a visit was made to Tobago and Trinidad. Our engineer, Mr. John Mills, went with us, and it is due chiefly to his intelligent and active interest that the remarkable success of the expedition was achieved.

We left New York on March 11 and returned on May 8, and although without letters of introduction to the officials of the Government of Tobago we were most courteously received and kindly welcomed by the Honorable Hubert Strange, the local governor, as well as by Messrs. Thomas E. Miller, H. R. Hamilton, and Harold de Pass, officials and prominent estate owners of this beautiful island.

Our expressions of gratitude are especially due to Albert H. Cipriani, esq., of Port-of-Spain, who generously placed at our disposal, free of rent, the excellent estate house at Pigeon Point, Tobago, which proved to be in all respects an ideal residence for our laboratory. Our most efficient and constantly helpful friend while here was Harold Kernahan, esq., manager of the large coconut estate of this end of the island.

While at Port-of-Spain, also, our expedition was significantly aided by advice and active assistance on the part of Mr. and Mrs. J. B. Rorer,

*Situated at Tortugas, Florida.

to whom we owe our introduction to Mr. Cipriani, as well as to Judge Blackwood Wright and others whose interest and kindness leave upon all of us a charmed impression of this most beautiful tropical island, a region wherein one may enjoy all the advantages of highly intelligent civilization and yet be surrounded by the most luxuriant and varied forest of the New World.

Being situated about 20 miles north of Trinidad, Tobago is separated from the muddy shore-waters which creep westward along the South American coast. The island, surrounded by pure blue ocean-water, lies directly in the course of the northern branch of the Great Equatorial Current of the Atlantic, which drifts upon this region from the distant coast of Africa. Thus the pelagic life of the tropical Atlantic is carried directly upon the shores of Tobago, and the island affords an unrivaled situation from which to study the floating animals of the warmest parts of the ocean, thus enabling the Director to make a notable addition to his observations and drawings of the siphonophores.

The greater part of the land area of Tobago is of igneous and plutonic rocks, much broken and eroded and covered on the high summits with primeval forest, but the low-lying southwestern end consists of an elevated coral-bearing limestone, which off Milford Bay and Pigeon Point is fronted by one of the richest fringing reefs of the West Indies. Dr. H. L. Clark found 75 species of echinoderms in this region, about one-quarter of which are new to science. The fauna of Tobago, both marine and terrestrial, shows distinct South American affinities and is thus richer than that of the other West Indian islands, there being only about 52 species of echinoderms known from Jamaica, while more than one-third of the Tobago species are not found at Jamaica. Among the most interesting echinoderms of Tobago is the crinoid *Tropiometra*, which is common in water from 1 to 5 deep feet over Buccoo Reef near Pigeon Point.

Dr. Mortensen, of Copenhagen University, who accompanied our expedition, raised this form, together with 9 other species of echinoderms, and he found that *Tropiometra* passes through a stalked and attached pentacrinoid stage. Dr. Clark found that it is remarkably resistant to changes both in temperature and salinity, and this, together with its commonness, and the ease with which the ripe eggs may be obtained in March and April, should make it a classic object for experimental work, *Tropiometra* being the only crinoid known to be abundant in the very shallow water of the entire American region.

Dr. Mortensen had been upon a world-tour, engaged in the study of the development of echinoderms, of which he has reared a larger number than have all other previous students of the group combined. He found Tobago to be superior to any other single locality he had previously visited for this purpose. Indeed, a limestone region is an essential for success in rearing most marine invertebrates in aquaria

supplied with coastal water, for the excess of calcium reduces the free CO_2 which is highly poisonous to most marine larvæ. The reduction of CO_2 is characteristic of those parts of the West Indian region wherein the surface-water is charged with a colloidal precipitate of $CaCO_3$ due to bacterial action, as determined by Drew, Kellerman, and Smith.

The following 14 investigators studied under the auspices of the Department of Marine Biology during the year:

Name.	Place and time of study.	Subject.
Paul Bartsch, U. S. Nat. Mus.	Florida Keys and Tortugas. May 15 to June 4.	Variations of cerions transplanted from the Bahamas to Florida.
H. H. M. Bowman, University of Pennsylvania.	Tortugas, and Miami, Florida, June 5 to Aug. 8.	Ecology and physiology of mangroves.
Lewis R. Cary, Princeton University.	Tortugas, June 23 to July 27...	Physiological reactions of *Cassiopea*. Growth-rate and ecology of reef alcyonaria.
Hubert Lyman Clark, Museum of Comparative Zoology, Harvard University.	Tobago, West Indies, Mar .21 to Apr. 23.	Echinoderms. Reactions of *Tropiometra*.
Ulric Dahlgren, Princeton University.	.. ..	Grant of $125 for the study of the electro-genic muscles of fishes.
Henry H. Donaldson, Wistar Institute of Anatomy.	Tortugas, June 23 to July 27 ..	Effects of climate upon white rats introduced into the tropics.
A. J. Goldfarb, College of City of New York.	Tortugas, June 11 to July 10 ..	Chemistry of fertilization in echini.
E. Newton Harvey, Princeton University.	.. ..	Grant of $850 for the study of the chemical nature of the light-producing substances of marine animals in Japan, May to September.
Shinkishi Hatai, Wistar Institute of Anatomy.	Tortugas, June 23 to July 27...	Assistant to Professor Donaldson. Physiology of starvation in *Cassiopea*.
William H. Longley, Goucher College, Baltimore.	Tortugas, May 24 to July 27...	Relation between color of fishes and that of their surroundings.
A. G. Mayer, Carnegie Institution of Washington.	Tobago, Tortugas...... ...	Siphonophores of the Atlantic. Effects of cations and of hydrogen-ion concentration upon nerve-conduction in *Cassiopea*.
J. F. McClendon, University of Minnesota.	Tortugas, June 11 to July 27...	Hydrogen-ion concentration of sea-water; synthesis and physiological analysis of sea-water.
Th. Mortensen, University of Copenhagen.	Tobago, West Indies, Mar. 21 to Apr. 23.	Embryology of echinoderms.
A. L. Treadwell, Vassar College.	Bermuda, June to July, with an artist and an assistant.	Marine worms of the family Eunicidæ.

The season in Florida extended from May 15 to the end of July, and the Tortugas Laboratory was visited by 8 investigators, not including the Director. In addition, Professor Harvey was sent to Japan and Professor Treadwell to Bermuda under the auspices of the Department, while Doctors Clark and Mortensen studied at Tobago.

Owing to the probable necessity for abandoning the Tortugas as a site for our principal laboratory, it seemed desirable to avoid introducing new investigators to this region, fearing that their work might suffer should they be obliged to go elsewhere to complete it. Moreover, it seemed necessary to send Professor Harvey to Japan and Professor Treadwell to Bermuda. The Department has found that while it is relatively inexpensive to start a research, its legitimate requirements are apt to draw heavily upon us as the work proceeds, new and expensive experiments with costly apparatus often being required. It is, however, the first aim of the Laboratory to maintain adequately every research which falls under its auspices, and with the generous support of the President and Board of Trustees it has been able to carry out this ideal in an efficient manner.

No limitation should be attached either to the scope or character of our research, provided it falls under the broad domain of marine biology. Thus practical problems should interest us when such fall within our scope and when we are exceptionally fitted to give aid to their solution. For some years the Bahama Government has been interested in the possible artificial culture of the sponge-beds of these islands, and as extensive experiments have been conducted in this field under the direction of Mr. E. Chase, at Sugar Loaf Key, Florida, His Excellency Sir William Allardyce, K. C. M. G., Governor of the Bahamas, was pleased to appoint, through the agency of the Marine Products Board, Mr. H. C. Christie, who thus made a study, under our auspices, of both the artificial and the natural sponge-beds of Florida in order that he might report to his Government upon their condition with a view to improving the sponge-fisheries of the Bahamas.

At Tortugas, Messrs. Bartsch, Bowman, Cary, Goldfarb, Longley, and Mayer continued the work they had commenced during or before 1915. Dr. Bartsch devoted a longer time than ever before to the study of the cerions he has transplanted from the Bahamas, Porto Rico, and Curaçao to the Florida Keys.

Dr. Bowman presents a report upon his ecological and physiological studies of mangroves, which he conducted at Tortugas and at Miami, Florida.

For Professor Longley's researches, a new 26-foot naphtha launch, the *Darwin*, having a glass bottom, and equipped to serve as a tender in diving, was constructed during the winter of 1915–16 by our chief engineer, Mr. John Mills. We also had made for his use an underwater camera in order that he might take pictures of the reef fishes in their natural habitat, viewing them as their enemies and associates must see them. By means of these aids to research, Professor Longley made a notable advance in his observations of the habits and colors of fishes in relation to the appearance of their surroundings, proving that protective coloration is a dominant factor in the ecology of reef fishes.

It is only within the past few years that the importance of hydrogen-ion concentration has been recognized in physiological reactions. Accordingly, Professor J. F. McClendon came to Tortugas to make a physiological analysis of the sea-water and to attempt to make up an artificial sea-water in a synthetic manner, his previous notable work upon the hydrogen-ion concentration and the buffer substances in blood having fitted him in an exceptional manner for undertaking this research. For this purpose, he was provided by the Laboratory with a potentiometer which had been standardized by the United States Bureau of Standards. He found that the hydrogen-ion concentration of Tortugas sea-water ranged from 8.1 to 8.22 PH, and that it was but little if at all affected by suspended silt due to stirring up of the bottom, as occurred during the heavy storm of July 4 to 6. As shown by L. J. Henderson, the bicarbonates of the sea-water, being only slightly dissociated, act as buffer substances to prevent any slight addition of acid from producing a marked change in the hydrogen-ion concentration.

Professor McClendon also made a physiological analysis of sea-water, finding that its gaseous content was very important, and that each liter of sea-water contained about 23.5 c. c. of 0.1 molecular NaOH, which is balanced against the CO^2, the pressure of which is 0.4 per cent of an atmosphere. Thus he found that an artificial sea-water could be made as follows: 1.0 molecular (NaCl 483.65 c. c.+NaBr 0.8 c. c. + KCl 10.23 c. c. + $NaHCO_3$ 2.32 c. c.) + 0.5 molecular ($MgSO_4$ 57.09 c. c. + $MgCl_2$ 50.21 c. c. + $CaCl_2$ 22.07 c. c.) + 373.63 c. c. of water. As a solvent of the salts one should use either rain-water or distilled water redistilled in a copper retort with a quartz condensing-tube, and then throughly aerated by bubbling air through it. Sea-water made according to this method sustained the vital activity of marine animals about as well as does natural sea-water. McClendon's method will doubtless be of great value in physiological work wherein artificial sea-water is required.

Certain of the results of these studies of McClendon were at once applied by Dr. Cary and Dr. Mayer in their work on the reactions of *Cassiopea*, the hydrogen-ion concentration of the solutions in which the animls were placed being determined both before and after the experiments. Using these data, Professor Cary redetermined the effects of the presence or absence of the marginal sense-organs upon the rate of the early stages of regeneration in *Cassiopea*, while Mayer redetermined the curve for the rate of nerve-conduction of *Cassiopea* in natural sea-water diluted with distilled water and also in various partial or complete sea-water solutions.

Professor Cary confirmed and made more precise his previous determination that when even a single marginal sense-organ is present the rate of the early stages of regeneration is more rapid than if a

sense-organ be not present, and in addition he found that if sense-organs be present the medusa starves more rapidly than if they be absent. Thus the general metabolism of the medusa is under the control of its nerve-centers.

Professor Cary also continued his study of the growth-rate of gorgonians, and his remarkable discovery that the gorgonians contribute more limestone to the Tortugas reef-flats than do the stony corals is so unexpected that he should be given an opportunity to visit the Pacific reefs in order to determine whether this be a general or merely a local condition. In accord with Vaughan's intensive studies of the Florida-West Indian region, this discovery of Professor Cary's tends to belittle the coral factor as a constructive agent in the building up of Atlantic coral reefs. Undoubtedly, however, the corals are a more important factor in the Pacific than in the Atlantic, and their effect in this greater ocean should be quantitatively determined.

Professor George A. Hulett, of Princeton University, was so kind as to direct Mr. John H. Yoe in the distillation of 144 liters of water by the well-known Hulett method, using the still in the Princeton laboratory. This water had a hydrogen-ion concentration, due to CO_2, of between 0.8 to 1.0×10^{-6}, and it was sealed in liter flasks of Pyrex glass, and thus transported to Tortugas to be used in physiological work. This water was used by Mayer to determine the rates of nerve-conduction in *Cassiopea* when placed in sea-water diluted with distilled water. The results suggest that sodium and calcium unite to form a chemical combination with some proteid element. Na, Ca, and K are the only cations necessary for nerve-conduction; Mg being nearly as inert as distilled water. The ion-proteid concerned in nerve-conduction has a high-temperature coefficient of ionization. The reaction is probably accelerated by an enzyne (Harvey, 1911). Recently Professor Ralph S. Lillie has stated in the *American Journal of Physiology* that the rate of nerve-conduction probably declines in the same ratio as the conductivity in diluted sea-water, and tests made by us, using Kohlrausch's method with Tortugas sea-water, showed that this appears to be true, but it is untrue for changes in temperature of the sea-water, the rate of nerve-conduction augmenting 2.5 times as rapidly as does the electrical conductivity as the water is heated. The rate of nerve-conduction, however, does not depend on the electrical conductivity of the sea-water, for it makes no significant difference whether the sea-water be diluted with distilled water or with 0.4 m. $MgCl_2$.

Professor A. J. Goldfarb conducted an important study of the effects of aging upon the ability of the sperm of individual male echini to fertilize the eggs of individual females. His report (pages 201–203) will indicate the character of his results. Unfortunately, the heavy storm of July 4 to 6 so agitated the echini over the Tortugas reefs that their eggs were rendered useless and the work was interrupted at a most

interesting stage, but it is hoped that it may soon be continued under better conditions.

During the summer of 1914, Professor Henry H. Donaldson placed upon East Key, Tortugas, 8 white rats, an albino of the Norway rat. These apparently increased and seemed to be numerous in the summer of 1915, but upon his visiting East Key in 1916, they were nearly extinct, for only two females could be captured in traps. Accordingly, in July 1916, Professor Donaldson brought from the Wistar Institute Laboratory, in Philadelphia, about 100 white rats, 60 of which he introduced upon East Key and 24 upon Garden Key. He intends to revisit the Tortugas in 1917 and to determine the effects of isolation, climate, and restricted food upon the brain-weight and general anatomy of these animals. He found that the food of the rats upon East Key, which is a small sandy islet covered with low bushes, consists of grass-seed and shore crabs (*Ocypoda*). They lack fresh water, excepting that derived from the occasional rains of this arid region and from dew. Thus their struggle for existence is uncommonly severe and their margin of safety must be reduced to a minimum. Professor Donaldson's report should be consulted by those interested in the effects of a tropical climate, combined with meager variety in food, upon rats accustomed previously to a wide variety of food in a temperate region.

Dr. Skinkishi Hatai assisted Professor Donaldson in the study of the white rats and also carried out an elaborate study of the decline in weight and the nature of the substances consumed in starving *Cassiopea*, the decline of various organs and parts of the body being determined. These studies, it is hoped, he will continue in 1917 at Tortugas. His preliminary report should be consulted by those interested in this subject. He found that there is a remarkable process of adjustment during starvation by virtue of which the proportional weights of the mouth-arms, disk, and velar margin become those of a normal *Cassiopea* of the size of the reduced animal. His results, although as yet incomplete, show an alteration of nitrogen content as starvation proceeds, thus resembling the condition observed in vertebrates. The loss of weight is practically controlled by the large relative amount of gelatinous substance.

Professor Edward L. Mark, of Harvard, director of the Bermuda Marine Biological Laboratory, was so kind as to extend to Professor A. L. Treadwell an invitation to make use of the facilities of the Bermuda laboratory in the study of the Eunicidæ. This research has been pursued by Professor Treadwell for many years, and he has accumulated a valuable collection of drawings. These studies have been conducted at Tortugas and Porto Rico, and it was therefore desirable that Professor Treadwell should visit Bermuda in order to determine the relationships between the polychæte fauna of the northern and mid-region of the range of this tropical family of worms. Accord-

ingly, the Department of Marine Biology made a grant to Professor Treadwell to enable him to visit Bermuda, accompanied by an artist and an assistant, and he thus spent five weeks at this well-equipped station. In his report he draws comparisons between the Tortugas and the Bermuda annelid faunæ.

Annually since 1898 the Atlantic palolo worm, *Eunice fucata* Ehlers, has swarmed at Tortugas at or near the period of the last quarter of the July moon, but occasionally at the time of the first quarter of the moon when the last quarter came later than July 20. In 1916, however, a dense swarm came on July 14, the day of the full moon, and an even more noteworthy swarm on July 20, the day of the moon's last quarter.

The following papers were published by agencies other than the Carnegie Institution of Washington during the year as a result of studies conducted partially or wholly under the auspices of the Department of Marine Biology:

Cary, Lewis R., 1916. The influence of the marginal sense-organs on the rate of regeneration in *Cassiopea xamachana*. Journal of Experimental Zoology, vol. 21, No. 1.

———, 1915. The influence of the marginal sense-organs on functional activity in *Cassiopea xamachana*. Proceedings National Academy of Sciences, vol. 1, pp. 611–616.

Clark, Hubert Lyman, 1915. Catalogue of recent Ophiurans: Based on the collection of the Museum of Comparative Zoology. Memoirs Museum Comparative Zoology at Harvard College, vol. 25, pp. 165–376, 20 plates.

Harvey, E. Newton. The mechanism of light production in animals. Science, n. s., vol. XLIV, pp. 208, 209, August 11, 1916.

———. The light-producing substances, photogenin and photophelein, of luminous animals. Science, n. s., vol. XLIV, pp. 652–654, November, 1916.

Mayer, Alfred G , 1916. Nerve-conduction and other reactions in *Cassiopea*. American Journal of Physiology, vol. 39, pp. 375–393, February 1916.

———, 1916. A theory of nerve-conduction. Proceedings National Academy of Sciences, vol. 2, pp. 37–42, 2 figs.

———, 1916. Submarine solution of limestone in relation to the Murray-Agassiz theory of coral atolls. Proceedings National Academy of Sciences, vol. 2, pp. 28–30.

———, 1916. Articles upon the history of Pacific islands. Scientific Monthly, vol. 1.

Pratt, Henry S., 1916. The trematode genus *Stephanochasmus* Loos in the Gulf of Mexico. Parasitology, vol. 8, No. 3, pp. 229–238, pl. 13, January 1916.

Vaughan, T. Wayland, 1916. The geologic significance of the growth-rate of the Floridian and Bahaman shoal-water corals. Journal Washington Academy of Sciences, vol. 5, No. 17, pp 591–600, October 1915.

———, 1916. The results of investigations of the ecology of the Floridian and Bahaman shoal-water corals. Proceedings National Academy of Sciences, vol. 2, pp. 95–100, February 1916.

Volumes 7 and 8 of Researches from the Department of Marine Biology were published, a quarto volume upon the researches pursued by our expedition to the Murray Islands in 1913, treating of the ecology of the coral reefs, the species of corals, and an analysis of rocks, sediments, bottom deposits, diatoms, and foraminifera, is about to be published by the Carnegie Institution of Washington.

Of the 17 colored plates for Dr. Clark's report upon the Murray Island echinoderms, 8 have been completed, the long delay being caused by war conditions which have profoundly affected Sydney,

Australia, where these plates are being lithographed under the direction of Mr. E. M. Grosse.

Papers are being collected for volumes 9 and 10 of Researches from the Department of Marine Biology, and it is hoped these may all be received before January 1917, in order that the work of printing the volumes may soon commence.

An unfortunate event of the year was the loss of the dory gasoline launch *Henderson*, which was a gift to the Laboratory by Hon. John B. Henderson, jr., Regent of the Smithsonian Institution. It was one of our most useful boats, but on the night of July 26 it was tied to the stern of the *Anton Dohrn* and within half an hour thereafter its absence was noted, the forward cleat having pulled out in the heavy sea and high wind. A search of 7 hours over the dark sea failed to discover the launch, which probably drifted out into the Gulf of Mexico and was swamped by the torrential rains and rough water of the following days.

We suffered neither loss nor damage through the storm of July 4 to 6, although part of the lighthouse dock at Tortugas was torn away. Our excellent anchors and new hawser held the *Anton Dohrn* in Fort Jefferson Harbor without accident, and the launches were similarly fortunate off Loggerhead Key.

It is a pleasure to record that the kindness and cordiality so constantly shown to us by successive commandants of the Key West Naval Station has been continued by the present commandant, Captain Warren J. Terhune, U. S. Navy, and his family.

REPORTS OF INVESTIGATORS.

Report on the Bahama Cerions Planted on the Florida Keys, by Paul Bartsch.

We visited the colonies near Miami on May 16, 1916. The old planting on the second key north of Sands Key is still doing well. Old and young were up on the bushes and the colony was spread over about the same extent of territory as it occupied last year.

The new colony (first generation of individuals grown in Florida), planted about 70 feet south of the original planting, is also surviving well, but no young individuals were found. It is possible that very small young specimens may be buried in the sand, but we did not deem it wise to disturb them.

On the first key north of Sands Key, where the "White House" type of cerions were planted, we found conditions similar to those on the second Ragged Key north of Sands Key, and here, also, we left them undisturbed. Members of the old colony were everywhere to be seen. The old marked shells were in good condition, and young in various stages of growth could be found everywhere.

We next visited Sands Key and examined carefully the ground where we planted a small colony of cerions grown in Florida two years ago, but our search failed to reveal a single specimen. I do not know why this colony should have perished, for some of the young shells planted here should certainly have matured; the locality seems ideal for cerions. The search we made was a thorough one, as all the conditions were most favorable for the work. Mosquitos were practically absent, a condition not observed during past seasons.

On May 19 we visited Indian Key, where we found the cerions doing well at both plantings. We gathered 18 living adult specimens of the first generation of Florida-grown individuals, and 31 of the originally imported specimens of the second planting. The Florida-grown individuals we measured and marked and placed about 5 feet east of the stone wall which is a remnant of a house on the eastern end of the key, while we replanted the 31 Bahama specimens a little west of the center of the second stone wall. The original planting, which we found completely swamped by a rank growth of vegetation two years ago, appears to have survived quite well, and this year the drought has been so great that the grass has been dried up to a great extent, even the cacti having a shriveled appearance; and this enabled us to see that the cerions had survived. We found 29 of the originally planted material, 49 adult Florida-grown individuals, and 15 young tips. We planted the Florida-grown individuals in one place at the inner edge of the grass, about 45 feet east and a little to the left of the stone wall, looking landward.

We next visited Tea Table Key, where a thorough search revealed not a single cerion. They have evidently all been destroyed and carried away by the crabs. The island was completely overrun by crabs two years ago, though now they seem to be practically absent.

On May 20 we visited Duck Key and found that part of the key where our cerions are planted so heavily overgrown with Bahama grass that it was impossible, in walking about, to reach the ground. The grass underfoot gave one the impression of walking on a thickly felted carpet. It was exceedingly difficult to determine whether any cerions remained. A long search yielded only 4 specimens, of which 3 belonged to the originally planted material. The single Florida-grown individual has a peculiar aperture and was reserved for the collection, while the other 3 were left at the planting.

We next visited Bahia Honda and found the old planting doing well. We gathered 22 full-grown specimens of the first Florida generation. Some of these shells were found fully 150 feet from the stake where the original planting was made. Not a single specimen of the originally transplanted material was found. It is quite possible that most of these perished in the fire to which we referred last year, which completely swept the region. This year's findings were largely confined to the inner edge of the ditch. The colony of the first generation of Florida-grown individuals which we planted on the seaward side of the ditch seems to be completely hidden in the very dense growth of Bahama grass and it will be necessary to cut this next year in order to collect the snails.

On May 22, at Newfound Harbor Key, we found that the colony on the upper ground, that is, the ridge upon which we had transplanted the colony, had been recently burned over, leaving the place quite bare. Here we discovered only a single specimen of the originally planted Bahama cerions and one locally grown individual. In the low flats, where we made our first planting, we found 51 individuals, which represent the first generation of Florida-grown specimens, and 3 of the originally planted colony.

We were surprised to find 4 shells which are undoubtedly hybrids between the introduced species and the native *Cerion incanum*. These were taken from bushes on which both introduced and local forms were present. These 4 specimens were taken to Washington for further observation. The remaining specimen we placed in a cluster of stumps about 30 feet west of the large trees in the open plain, and marked the place with a stake. In this connection it might be well to say that when we made the first planting no specimens of the Florida cerions were observed on the island. If we had found them I doubt if we would have placed a colony on this little key, as

the original intention was to avoid making a cross between the local and the introduced forms.

On Garden Key, Tortugas, we found only a single specimen of the cerions planted. No trace of the second planting within the fort was found. The burning to which they were subjected last year seems to have exterminated them, so that the Garden Key colony, as a whole, is practically a failure.

On the other hand, on Loggerhead Key most of the colonies are doing very well, but nowhere did we find an adult specimen of the second generation. Judging from the large number of young individuals, there is no doubt that the coming year will yield a great number of this most interesting generation.

Condition of Colonies on Loggerhead Key, Tortugas.

Colony A. Young and adults were everywhere in evidence at this colony, which seems to be in an extremely flourishing condition. We left the snails undisturbed.

Colony B. This consisted of a planting of 500 tips of first-generation Florida-grown "White House" type cerions. We gathered 73 adults and 4 half-grown individuals. Last year we took from this same colony 139 specimens which, after measuring, we replanted as Colony J. This shows that at least 202 of the 500 tips reached or almost reached maturity. Measurements and photographs were taken of this year's specimens. They were placed with the remnant of Colony C.

Colony C. Very few shells were apparent in this colony, and since there is a possibility that there might be young individuals buried in the sand, we did not deem it wise to disturb the ground by walking over it and making a careful search for shells, since under no circumstances could adults of the second generation have appeared. In addition to the snails added from Colony B, we also placed here the 7 living specimens remaining of Colony J.

Colony D. Two dead shells only were observed. The painted cerions appear not to be well suited to this condition.

Colony E. This colony resembles Colony A in spreading over a wide area, and many young, and also adult shells, could be seen everywhere.

Colony F. This colony, which was planted in 1914, is doing remarkably well. We gathered 300 tips of the first generation, which I have replanted as Colony M. Of the originally planted shells, 178 were easily found, and these we placed again near the stake.

Colony G. We gathered 78 adults of the first generation of Florida-grown specimens of this colony, which were photographed and measured and returned to the stake marking this colony.

Colony H. This colony has again been subjected to a burning and I doubt if any cerions have escaped.

Colony I. This mixed colony, which is a replanting of the original material planted at Colony H, seems to be doing fairly well at its new location. We easily recovered 83 specimens of the originally planted "Kings Road" type, of which 28 were dead, and 115 specimens of the originally planted "White House" type, of which 27 were dead. We also found 18 young, probably belonging to the "White House" type. All of these we placed near the stake.

Colony J. Here we placed 139 specimens of the first generation of Florida-grown "White House" type cerions taken from Colony B last year. Of these we recovered 121 this year, all but 7 of which were dead. The 7 living specimens we have combined with Colony C.

Colony K. This colony appears to be in thriving condition.

Colony L. This colony, consisting of the 800 Porto Rico cerions planted last year, is doing well. We made no attempt to gather the snails.

New Colonies.

The two new colonies planted this year are:

Colony M 300 tips from Colony F, of the first generation of "Kings Road" type cerions of the 1914 planting. This new colony is placed a little south of the entrance stake to the original "Kings Road" type colony. It is on the inner edge of the outer sand-dune.

Colony N. 8317 specimens of a species of cerion gathered by Dr. Ralph Arnold on Curaçao, Netherlands West Indies. This is placed at the southeastern end of the large central meadow at the southern end of the island. We cleared this field of cactus to render observations less arduous next year.

Boca Grande Key.

The second colony on Boca Grande Key, consisting of first generation of Florida-grown individuals, was, I believe, completely destroyed by fire this year; but at the original planting many shells were seen upon the grass and bushes in the little meadow which is separated from the outer by a fringe of low bushes. It will be remembered that the original planting was visited by fire last year; the remnant in the location above referred to escaped burning and may continue the race.

A detailed report of the first generation of Florida-grown cerions, of which there is a large series on hand from most of the colonies, will appear soon, giving measurements, illustrations, and a general discussion of the data.

Report on the Colony of the Florida Tree Snails transplanted from Miami to the Tortugas and Key West, by Paul Bartsch.

In Year Book No. 14 of the Carnegie Institution (pp. 196–197, 1915) attention was called to the attempted colonization of this magnificent mollusk, which is threatened with extermination in the region of Miami, upon some of the southern keys. 318 specimens were transplanted, of which 113 were placed in the trees situated in the angle between the main road and first path to the left within the fort on Garden Key, 92 were placed in various kinds of shrubs and trees around the Laboratory on Loggerhead Key, and 101 were planted in the small groves of cordia trees on the east side and a little north of the light-house on Loggerhead Key. The remaining 12 were placed in trees near the commandant's residence at the naval station at Key West. A careful search in all these places failed to reveal a single shell and, unless these mollusks have burrowed in the ground or hidden away in knotholes or crevices which I was unable to discover, this experiment will have to be considered closed and a failure.

Birds Observed in 1916, in the region of Miami and the Florida Keys from May 15 to June 4, and along the Railroad from Key West to Miami on June 24, by Paul Bartsch.

During the past three years a list of the birds observed in southern Florida and on the off-lying keys has been published in each Year Book of the Carnegie Institution of Washington. Similar observations were continued this year, resulting in a total list of 54 species, of which 8 are additions to the lists which I have previously published. These represent the following species: Little blue heron, Florida clapper-rail, turnstone, Everglade kite, short-eared owl, chuck-will's-widow, wood pewee, and purple martin. This addition brings the total number of species observed during the past four seasons to 97. The season at which the observations were made would lead one to believe that almost all of the species listed are breeding birds.

The following table gives a summary of the previously published notes:

TABLE 1.

Year.	No. listed.	Additions.	Total listed.	Time of year.
1913	57	..	57	Apr. 20 to 30.
1914	46	19	76	Apr. 25 to May 9.
1915	38	13	89	June 17 to July 1.
1916	54	8	97	May 15 to June 4 and June 24.

It seems very desirable to have some observations made during the migrating season in order to establish records of the species that use these keys as stepping-stones in their journey to and from the West Indian Islands and the mainland beyond.

May 15, Miami: Red-bellied woodpecker (mating), mocking-birds, purple martins, boat-tailed grackles.

May 16, Miami: About the harbor we noticed 4 laughing gulls, a least tern, 8 man-of-war birds, and 3 brown pelicans. The laughing gulls consisted of adult and immature individuals.

Second Ragged Key north of Sands Key: Here we noted 2 green herons, a Florida yellowthroat, and many redstarts, both male and female. They were all fluffed up, as they usually are after a long journey. They probably arrived very recently. One wonders if it is the long journey or the lack of fresh water on these islands that gives to these migrant birds the peculiar puffed-up, fluffy appearance, characteristic of all the migrating birds observed on these keys.

First Ragged Key north of Sands Key: Redstarts in abundance, and a few Florida yellowthroats.

Sands Key: The absence of mosquitoes, owing to the lack of rain, made a thorough exploration of Sands Key possible, but the effort revealed few birds. Redstarts everywhere, a few Florida yellowthroats, 2 Florida cardinals, and 2 Key West vireos constituted our whole list.

We returned to our landing in the Miami River after sundown. The bright moonlight stimulated the mocking-birds to outdo themselves in song. In this they were joined by a chuck-will's widow, whose measured notes came to us from the farther bank of the river.

May 17: In a trip taken through Brickle's Hammock this morning, the following birds were seen: Boat-tailed grackles, Florida cardinals, Florida blue jays, gray kingbirds, ground doves, and mocking-birds.

In the afternoon we visited Mr. Simpson's place, "The Sentinels," on Little Rivers, where the following birds were seen: several Florida cardinals, a lot of boat-tailed grackles, a pair of Key West vireos, Florida blue jays, Florida yellowthroats, ground doves, yellow-billed cuckoos, mocking-birds, and an Everglade kite flying over the mangrove thickets fringing the bay, the first which I have seen for a long time.

In Biscayne Bay we saw laughing gulls, least terns, and man-of-war birds.

May 18: Visited Cape Florida, where we saw a few royal terns on the stakes marking the channel, 8 Florida cormorants on a piece of driftwood, a man-of-war bird, several Florida cardinals, and a pair of gray kingbirds.

May 19: In sailing down Hawk Channel between Cape Florida and Indian Key, only a few laughing gulls and 2 man-of-war birds were seen.

Indian Key: We saw 3 laughing gulls, least terns, a turkey buzzard, man-of-war birds, 2 red-bellied woodpeckers, and a nesting colony of boat-tailed grackles.

Tea Table Key: We found the red-bellied woodpecker, the ground dove, and the Florida cardinal.

May 20: A male parula warbler paid us a visit at our anchorage off Indian Key, and after fluttering about on deck for a few moments set out for shore. He seemed so exhausted that I doubt if he reached it.

Revisited Indian Key: Examined some of the boat-tailed grackles' nests, which are bulky structures placed in the low, thorny acacia trees, and found that they contained eggs. We also observed ground doves and an osprey, two birds we had seen yesterday.

We next visited Duck Key and found a rather remarkable assemblage of birds for so small an island, scarcely 60 yards in diameter: osprey, least tern, boat-tailed grackle, gray kingbird, Florida yellowthroat, king-fisher, Florida clapper-rail, man-of-war bird, and 4 great white herons. There was a large wooden box on the island, lying on its side, the inside of which, judging from the chalking and feathers it contained, seemed to be used as a shelter by these herons. The same signs would indicate that they also use the small mangrove clump as a roosting-place. Our visit forced the birds from the island, and we noticed, on coming through an arch of the viaduct, that they had settled upon the four adjacent telegraph poles, which project about 20 feet from the water along the track. The effect of these huge white birds capping these poles was rather striking.

Bahia Honda Key: On this key we saw 2 turkey buzzards, 2 laughing gulls, 2 Bahama red-winged blackbirds, 6 boat-tailed grackles, a man-of-war bird, and a flock of 12 brown pelicans.

May 21: We visited the sponge plantation on Chase's Key. In order to reach Mr. Chase's residence, we passed along the railroad tracks for about 3 miles, crossing Sugarloaf Key proper, Hart's Key, and Chase's Key.

On Sugarloaf Key we saw great white herons, Bahama red-winged blackbirds, boat-tailed grackles, an osprey, turkey buzzards, gray kingbirds, mocking-birds, white-crowned pigeons, ground doves, Florida cardinals, Florida crow, Wilson's plover, American egret, Louisiana heron, Ward's heron, yellow-crowned night heron, and the Key West vireo.

While on Hart's Key we found the Ward's heron, Louisiana heron, Wilson's plover, and the yellow-crowned night heron.

On Chase's Key the following birds were seen: Louisiana heron, boat-tailed grackle, Bahama red-winged blackbird, ground dove, many turkey buzzards, red-bellied woodpecker, black-crowned night heron, osprey, a pair of broad-winged hawks, and the little blue heron.

May 22: Passing the small key north of Newfound Harbor Key, we saw 3 brown pelicans, 2 laughing gulls, and a least tern.

While on Torch Key we found man-of-war birds, laughing gulls, least tern, and royal tern.

We next visited Big Pine Key and explored about half a mile of the southern end of it. During our stay here we saw the following birds: Key West vireo, mocking-bird, Bahama red-winged blackbird, boat-tailed grackle, Florida cardinal, red-bellied woodpecker, gray kingbird, a Florida red-shouldered hawk, and a summer tanager.

In the afternoon we visited Newfound Harbor Key, where my cerions are planted, and here saw boat-tailed grackle, a Louisiana heron, red-bellied woodpecker, and a gray kingbird.

We next called at the Great New Harbor Key and saw the boat-tailed grackle, Louisiana heron, red-bellied woodpecker, and a gray kingbird.

The two little keys seaward from the main harbor were next visited. In the southern one of these about 250 man-of-war birds were roosting in the

mangrove trees. There were also about 40 brown pelicans similarly disposed. Here, too, we found a small rookery of the Louisiana heron and 4 white-crowned pigeons, a bird not noted on previous trips. There were also gray kingbirds and quite a lot of breeding boat-tailed grackles, a few laughing gulls, and two royal terns.

On the little key to the north of this we saw brown pelicans, least tern boat-tailed grackles, gray kingbirds, laughing gulls, and red-winged blackbirds.

May 23: This morning we paid another visit to the little key in which the Louisiana herons have a small rookery. We found that some of the nests of this little heron contained eggs, while in other instances quite large young birds were present. We also noted man-of-war birds, brown pelicans, some laughing gulls, white-crowned pigeons, boat-tailed grackle, gray kingbird, least tern, and a couple of royal terns.

Arrived at Key West shortly after 1 p. m. About the harbor we noticed laughing gulls and a few man-of-war birds.

May 24: Made a visit to the Sambo Key, where the following birds were seen: laughing gull, royal tern, brown pelican, man-of-war bird, least tern, and a few noddy and sooty terns.

May 25: Saw a few small flocks of sooty and noddy terns over Key West Harbor this morning; also some man-of-war birds and a few laughing gulls.

On our way between Key West and the Tortugas we saw a few laughing gulls, a number of man-of-war birds, and a few royal terns only.

In the afternoon I made a trip through Loggerhead Key and noted 4 barn swallows, a yellow-billed cuckoo, a wood pewee, and a warbler, which probably was a yellow palm warbler.

May 26: On an early morning walk from the Laboratory to the lighthouse and up along the western shore, I noticed a gray kingbird, 2 barn swallows, a yellow palm warbler, and 2 Wilson's plovers. In the afternoon we made a visit to Fort Jefferson, where I saw the following birds: least tern, sooty tern, noddy tern, royal tern, a few boobies on the stakes outside of the fort, some man-of-war birds, and laughing gulls.

May 27: In an early morning walk around the island I saw a gray kingbird, a barn swallow, and 1 male and 3 female bobolinks. In the afternoon we again visited Fort Jefferson, where the following birds were noted: boobies on the stakes marking the channel, least tern, royal tern, sooty tern, noddy tern, laughing gulls, and man-of-war birds.

May 28: On an early morning trip through the island, a yellow-billed cuckoo, least tern, a night hawk, and a man-of-war bird were seen; also 2 owl pellets at the farther end of the island. These, when submitted to the experts of the Biological Survey at Washington, were believed to be products of the short-eared owl. One of these was said to consist of feathers and the other of hair and a few small bones of a *Paromyscus*. In the afternoon I observed 5 females and 1 male bobolink, a least tern, a couple of barn swallows, and a Ward's heron.

In order to determine the species of the night hawk on the key, I shot a specimen (several more were seen on the following day). The specimen shot proved to be a female and on comparison at Washington I am in doubt as to what it really is. Of course it is a subspecies of *C. virginianus*, but it will be necessary to secure a male to make certain the particular race to which it belongs. The character presented by the female suggests that it will probably prove to be a new race.

May 29: In walking through the island this morning I noticed: barn swallow, sooty tern, least tern, a single pair of the latter nesting at the south end of the island, wood pewee, bobolink, and a night hawk.

May 30: In a walk through the island this morning I noticed a gray kingbird, sooty tern, a few barn swallows, man-of-war bird, least tern, and a wood pewee. In the afternoon we paid a visit to Bush Key. Here we found about 500 least terns, many of them nesting. There are really two colonies on this key—one is on what used to be called Long Key, which is the old nesting site, and is now united with Bush Key at low tide; the smaller colony is at the farther end of Bush Key. On these keys we also saw the following birds: sooty tern, noddy tern, royal tern, brown pelican, man-of-war bird, Ward's heron, laughing gull, and several turnstones. The laughing gull was heckling the Ward's heron away from the shore. I strongly suspect that the laughing gulls hover around the rookery and plunder the least-tern nests, for they followed us closely in our wanderings. Most of the least tern nests contained only a single egg.

We next visited East Key, but found only a few least terns present.

On our way back we saw a barn-swallow, about half a mile off Middle Key.

On the buoys about Bird Key three boobies and a couple of royal terns were present, while the key itself contained the usual flock of noddy and sooty terns and quite a number of man-of-war birds.

In the evening I paid a visit to the tall dead sisal stalk in the center of the island with a hope of seeing the owl which produced the pellet I found the other day, and although I had been told by the light-house keeper that he had seen a hawk on the sisal stalk early in the evening, I was unable to find either bird. Subsequent efforts were also unsuccessful.

May 31: Visited Bird Key after breakfast. The noddy and sooty terns seemed to be just about as abundant as they were a year ago, but the man-of-war birds have increased greatly in number. There must be at least 300 present. Mr. Betel, the present warden, is doing excellent work in caring for this colony. He has been planting some bay cedars to restore those which were killed by the hurricane. A trip to the south end of Loggerhead Key disclosed the remains of a female bobolink, probably eaten by the owl.

June 1: Revisited Bird Key, but nothing new was added. The feathers of a yellow-billed cuckoo were found near the place where the bobolink was killed night before last; probably also killed by the owl.

June 2: The barn swallow and the wood pewee have disappeared.

June 3: In a walk through Loggerhead Key I noticed the least tern, a few sooties and noddies, and man-of-war birds, but no smaller birds.

June 4: We left Tortugas for Key West early this morning and in passing we noticed the usual group of noddies and sooties and man-of-war birds, some boobies and royal terns on the stakes, and a colony of least terns flying over Bush Key. We arrived at Boca Grande Key early in the afternoon, and during a hasty visit saw only a few brown pelicans and a couple of royal terns.

The following morning I sailed for Cuba, returning to Florida on June 23. The accommodation train from Key West for Miami is very slow and gives good opportunity to take detailed observations in passing over the elevated fills and viaducts intervening between Key West and the mainland. The train leaves Key West about $6^h\ 30^m$ in the morning and arrives at Miami about $2^h\ 30^m$ in the afternoon. I shall simply mention the name of the key and cite the birds seen on each one.

Birds seen between Key West and Miami.

Key West: Man-of-war bird, boat-tailed grackle.
Stock Island: Boat-tailed grackle.
Boca Chica Key: Boat-tailed grackle, one American egret, and a Ward's heron.
Big Coppit Key: A small flock of least terns, a Ward's heron, 5 great white herons, 3 osprey, boat-tailed grackle, and Bahama red-winged blackbird.
Chase Key: Gray kingbird, red-winged blackbird, 3 white-crowned pigeons, osprey, 2 turkey buzzards, 2 American egrets, and a great white heron.
Sugar Loaf Key: Boat-tailed grackle.
Cudjoe Key: Two white-crowned pigeons, Key West vireo.
Ramrod Key: Ward's heron.
Big Pine Key: Wilson's plover, 6 black-crowned night herons, boat-tailed grackle.
Spanish Harbor: Osprey, boat-tailed grackle, gray kingbird, least tern.
Bahia Honda: Gray kingbird, Ward's heron, Bahama red-winged blackbird.
Pigeon Key: A small flock of least terns, royal tern, laughing gull, and a brown pelican.
Marathon: A small flock of brown pelicans, 5 white-crowned pigeons, and boat-tailed grackles.
Long Key: American egret, osprey, green heron, brown pelican, and 5 Ward's herons.
Off Indian Key: Ward's heron, great white heron, brown pelican, least tern, laughing gull.
Isla Morada: Turkey buzzard, Florida cardinal, boat-tailed grackle, Bahama red-winged blackbird.
Plantation: Turkey buzzard.
Tavernier: Bahama red-winged blackbird, turkey buzzard, osprey, red-bellied woodpecker, boat-tailed grackle.
Round Harbor: Turkey buzzard, boat-tailed grackle, Bahama red-winged blackbird.
Everglade: Black-crowned night heron, 5 turkey buzzards, osprey, Ward's heron, crow, Bahama red-winged blackbird.
Florida City: Gray kingbird, turkey buzzard, boat-tailed grackle.
Homestead: Mockingbird, ground dove.
Rockdale: Night hawk, mockingbird, gray kingbird, Florida jay, bobwhite, Bahama red-winged blackbird, turkey buzzard.
Kendall: Mourning dove, Bahama red-winged blackbird, loggerhead shrike, mockingbird.
Larkin: Little sparrow hawk.
Miami: Ground dove, Florida blue jay, little sparrow hawk, mocking-bird, loggerhead shrike, red-bellied woodpecker, Florida cardinal, and night hawk.

Scientific Equivalents for Common Names of Birds Used in Preceding List.

Laughing gull = Larus atricilla.
Royal tern = Sterna maxima.
Least tern = Sterna antillarum.
Sooty tern = Sterna fuscata.
Noddy tern = Anoüs stolidus.
Red-footed booby = Sula piscator.
Florida cormorant = Phalacrocorax auritus floridanus.
Brown pelican = Pelecanus occidentalis.
Man-of-war bird = Fregata aquila.
Great white heron = Ardea occidentalis.
Ward's heron = Ardea herodias wardi.
American egret = Herodias egretta.
Louisiana heron = Hydranassa tricolor ruficollis.
Little blue heron = Florida cærulea.
Green heron = Butorides virescens virescens.
Black-crowned night heron = Nycticorax nævius.
Yellow-crowned night heron = Nyctanassa violacea.
Florida clapper rail = Rallus crepitans scotti.
Wilson's plover = Ochthodromus wilsonius.
Ruddy turnstone = Arenaria interpres morinella.
Florida bobwhite = Colinus virginianus floridanus.
White-crowned pigeon = Columba leucocephala.
Mourning dove = Zenaidura macroura carolinensis.
Ground dove = Chæmepelia passerina terrestris.
Turkey vulture = Cathartes aura septentrionalis.
Everglade kite = Rostrhamus sociabilis.
Florida red-shouldered hawk = Buteo lineatus alleni.
Broad-winged hawk = Buteo platypterus.
Little sparrow hawk = Falco sparverius paulus.
Osprey = Pandion haliaëtus carolinensis.

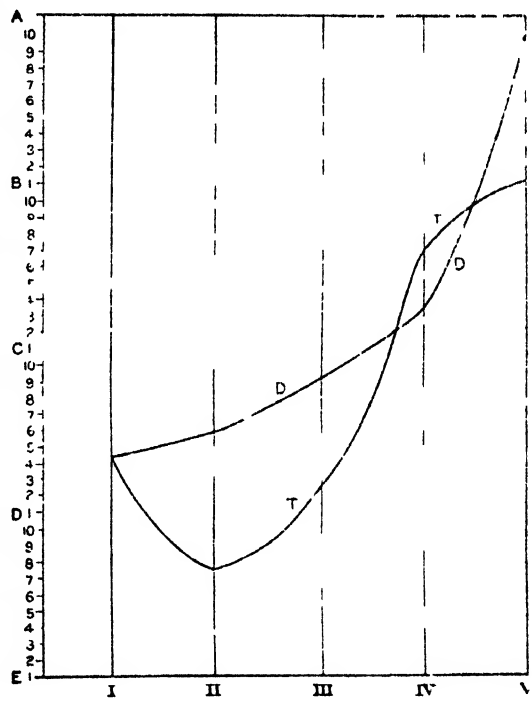
Short-eared owl = Asio flammeus.
Yellow-billed cuckoo = Coccyzus americanus americanus.
Belted kingfisher = Ceryle alcyon.
Red-bellied woodpecker = Centurus carolinus.
Chuck-will's widow = Antrostomus carolinensis.
Night hawk = Chordeiles virginianus virginianus.
Night hawk (subspecies?) = Chordeiles virginianus ——?
Gray kingbird = Tyrannus dominicensis.
Wood pewee = Myiochanes virens.
Florida blue jay = Cyanocitta cristata florincola.
Florida crow = Corvus brachyrhynchos pascuus.
Bobolink = Dolichonyx oryzivorus.
Bahama red-winged blackbird = Agelaius phœniceus bryanti.
Boat-tailed grackle = Megaquiscalus major major.
Florida cardinal = Cardinalis cardinalis floridanus.
Summer tanager = Piranga rubra rubra.
Purple martin = Progne subis subis.
Barn swallow = Hirundo erythrogastra.
Loggerhead shrike = Lanius ludovicianus ludovicianus.
Key West vireo = Vireo griseus maynardi.
Parula warbler = Compsothlypis americana americana.
Yellow palm warbler = Dendroica palmarum hypochrysea.
Florida yellow-throat = Geothlypis trichas ignota.
Redstart = Setophaga ruticilla.
Mocking-bird = Mimus polyglottos polyglottos.

Report on Botanical Investigation at Tortugas Laboratory, Season 1916, by H. H. M. Bowman.

In this second season of the author's investigation at the Tortugas Laboratory some of the same series of experiments on the physiology of mangroves has been carried on as in the season of 1915, but in a more extended manner. Part of the season was also utilized in making experiments on the mangroves of a chemico-physiologic nature.

The first half of this season was consumed in making a large number of tests of *Rhizophora* seedlings to learn if possible the relation between the tannic-acid content of the hypocotyl and the dextrose content of this organ in the plant's economy. With this end in view, seedlings were carefully selected from material growing on the beaches at Bush Key and Loggerhead Key, and graded according to length of hypocotyl, length of leaves, etc. Equal weights of these hypocotyls constituted the material tested, the differences in size in the plants being generally interpreted as differences in age, but all the seedlings were apparently dropped from the parent trees in February or March of the same year. This uncertainty of age was rather disturbing to the investigator, since it can not be known through what vicissitudes the seedlings may have gone during the interval in which they were floating in the sea—that is, from the time the hypocotyl was dropped till it became anchored and the roots put out. This point seems to be of considerable importance, since some hypocotyls are broken and often seriously injured in their journey of perhaps several weeks on the sea, until they come to an anchorage. Some seedlings with the plumule broken off will later send out several buds from the lenticels farther down on the neck of the hypocotyl, but this decreases the reserve food in the organ, and in the tests made this season all such seedlings were rejected. It is the author's hope to spend a longer time on this problem and test only seedlings which have been plucked from the trees just before they would have fallen naturally. They will then be planted in moist sand, so that the age of all plants will be definitely known, and the plants kept under controlled conditions; however, this can only be realized in a permanent tropical laboratory.

As intimated above, equal weights of the selected hypocotyls were taken and ground up in a mortar, extracted with distilled water, and the extract filtered. These extracts were made both by infusion and decoction, in different instances, but the resulting differences in strength were negligible. The filtered extracts were treated with certain reagents and tested for tannic acid and dextrose by colorimetric methods. Quantitative methods were not feasible at the laboratory, so after trying many special tests and reagents, Hager's test for tannic acid and Huizinga's test for glucose were decided upon as the most practicable under the peculiar conditions obtaining and with the available supply of material. The details of these tests and the technique used in handling this mangrove material will be given in a subsequent paper. In all, over 90 tests were made in the few weeks devoted to this portion of the season's work, including the preliminary experiments in working out the best method in dealing with the material. Control solutions of varying strengths were made up afresh for each series of tests, both of Merck's standard tannic acid and Kahlbaum's standard dextrose. In checking up the results of the tests, arbitrary standards of extract were made by comparison with the control solutions of known percentage content. These standards were of six grades, each approximating a certain percentage of tannic acid or dextrose.



I once thought there might be some definite relation between the amounts of the substances in the hypocotyls of different ages and with different growth conditions—for instance, that with increasing growth the tannic-acid content of a hypocotyl might decrease, with perhaps a corresponding increase in the sugar content. In the light of these preliminary tests, this does not seem to be the case, but with increasing growth and expansion of the protosynthetic tissues in the older seedlings and the transformation of the starch stored in the hypocotyl, the sugar increases in a steady upward curve. In the case of the tannic acid, however, such is not the case; there is a decrease in this substance in the young seedling just pushing out roots and unfolding the plumule, then with later growth and greater synthetic activity there is a slight regular increase in tannic acid. The behavior of this curve can not be explained just yet, although the author hopes to give the biological interpretation of this fact when the data have been worked out to a fuller degree and a larger series of experiments made on this particular phase of the problem with better controlled conditions for the sprouting hypocotyls. A condensed graph of the tendency of variation in the amounts of dextrose and tannic acid in *Rhizophora* hypocotyls is given herewith. While these experiments were being conducted on the dextrose and tannin contents, a series of tests were made to determine the presence of the enzyme, tannase in the hypocotyl of *Rhizophora*. Definite weights of selected

hypocotyls were ground up and extracted with distilled water and filtered. The filtrates were then divided and one-half boiled several minutes. To both solutions a small quantity of standard tannin was added and both placed in an incubator at 40° C. for 24 hours. After allowing this time for the anticipated enzyme to effect changes in the tannin content of the liquids, both the control flasks and those containing the unboiled extract were treated with ferric chloride to cause precipitation, with corresponding change in color. In some of these tests the precipitate was filtered off and after repeated washings was desiccated and weighed, but in none of the tests was there any conclusive evidence of the presence of the enzyme tannase in the hypocotyl of *Rhizophora*.

The balance of the season, after the conclusion of the above tests, was devoted largely:

First.—To a continuation of the work on the transpiration-rate measurement of *Rhizophora* seedlings planted in different conditions of soil, light, and shade, and varying concentrations of fresh and salt water. These seedlings were planted in large glass beakers, or jars 8 inches in diameter and about 10 inches deep, 3 seedlings to a jar. These plants also were secured at Bush Key of the Tortugas group in quantity sufficient to fill about 50 jars. The seedlings are not plentiful in the Tortugas, most of them having probably drifted from the Marquesas Atoll, and on being cast up on the north and east shores of the Tortugas have taken root on the beaches in the moist sand and débris of seaweed, etc., where they survive for several months till the moisture fails or they have exhausted their reserve supply of food in the hypocotyls. These seedlings were carefully and speedily transferred in pails of moist sand to the laboratory and selected ones planted in the jars. All broken and injured plants were rejected and an effort was made to keep all of as uniform a size as possible. While this supply of the material was limited, the plants grew much more rapidly than those used in the previous year's experiments on transpiration-rate measurement. These plants had been brought on the yacht from Cayo Agua, about 86 miles east of the Tortugas, and did not very well bear the transplanting from their natural beds under the old trees in the swamp to the laboratory.

These jar cultures were started the second day of the season's work, so that the plants might make some growth and be free from the shock of transplantation when time came for the transpiration-rate records to be taken. The records were made mostly during the middle portion of the day, so that conditions were as uniform as might be. The Stahl method of estimating the rate of transpiration was used. Disks of fine filter-paper were saturated in cobalt-chloride solution and dried. These papers were put in a Ganong leaf-clasp and the rate at which the paper changed color was noted for each test. Very striking and clear differences in rate were observed in the experiments this year, as were those of the previous season. The solutions and soils, however, of this season's work were different from those of last year.

The mass of records of these tests has not yet been tabulated for this season's work, and no idea of the results can be given in this preliminary report. Some of the plants of this series of experiments were left in moist soil only, out-of-doors, over the winter period of 1915–16, and on opening the laboratory season this year one flourishing young *Rhizophora* plant was found to have grown 8 cm. under very adverse conditions in the Tortugas climate between August 1915 and June 1916. This is the longest survival of any of a series of mortality experiments which the author made in the 1915 season.

One phase of these mortality experiments which was not repeated this year was that of *Rhizophora* cultures in superconcentrated sea-water; neither were transpiration-rate records taken for such cultures this season. Not only were the leaves of *Rhizophora* tested by the Stahl method, but the author devised a special instrument for the purpose of getting the rate of transpiration on the long, pendulous prop-roots of older trees. This special clasp is made to contain the indicator-paper just as in a Ganong clasp, but was designed to fit the cylindrical contour of the roots and is operated by a spring which is, in the author's estimation, an improvement on the older type of instrument. A more detailed description of this instrument and the results of these tests on old trees, taken *in situ*, will be given later and in a fuller manner than can be here presented. As there were no old trees at Tortugas, these observations were made along the Miami River and in Biscayne Bay, together with physiologic observations of a different character. The above region offered an ideal locality for observing the transpiration-rate through the lenticels of the pneumatophore prop-roots of the old trees, because the river and bay together afford all the varied conditions from fresh to salt water. These results also will be tabulated and published in the full paper dealing with this work.

Second.—Besides the work just noted, the latter portion of this past season's work was the gathering of material to finish the author's paper on the botanical ecology of the Tortugas region, which will appear as a contribution from the Tortugas Laboratory. This work was begun in the early part of 1915, and specimens were taken and observations made at intervals since that time. The peculiar climatic conditions of the group make a study of the flora of this region most interesting. The vegetal sequence in these islands and the factors in dissemination are also worthy of even more intensive study than the investigator has been able to devote to them in the few weeks the Laboratory is open during the year. The writer used a portion of the latter half of the season in making a series of carefully plotted distributional maps, with the aid of a plane-table and sighting-rule. These will aid in illustrating the factors concerned with dissemination in these islands.

Among the observations pertaining to this work a considerable number of potometric records were taken on all the main species of the Tortugas flora, such as *Tournefortia*, *Suriana*, *Canavali*, etc. The transpiration records were taken with a graduated Ganong potometer under several conditions, as sun and shade, etc. This data is very striking and illustrates the extreme adaptation of these plants to conserve moisture.

Supplementing the observations on the spermatophytes of the region, a full collection of the marine algæ of the reefs has been made, both herbarium specimens and material in liquid preservatives being secured. This collection was made possible by the use of a diving helmet and also by the utilization of the deep-sea dredging apparatus with which the Laboratory's yacht is equipped. The list and distribution of these algæ will probably be used in connection with the ecologic paper.

While dredging out in the Gulf of Mexico, on the edge of the Gulf Stream, in 12 to 17 fathoms of water, an effort was made by the writer to again secure specimens of that curious little submerged spermatophyte, *Halophila*, which the author described in a recent publication as occurring at unusual depths. Hopes were entertained that the staminate form might be collected, but the expedition was without success in this, though plenty of material was collected of two species of *Halophila* to pursue some further research on this interesting genus.

While collecting algæ, the investigator happened to find another submerged aquatic in its blooming period. This was the diœcious plant *Thalassia testudinum*. Both sexes were collected and the manner of pollination was studied in the Laboratory, as well as the germination of the pollen-grains. Of this latter subject a number of drawings were made.

The Laboratory closed on July 27, but the author was furnished by the Director with a launch and a man to continue his research about 200 miles north of the Tortugas, on the mainland of Florida, in the vicinity of Miami, as mentioned above. Here, in addition to the taking of transpiration-rate records on the pneumatophore prop-roots of old trees, the writer made an extensive series of hydrometric observations on the waters of the Miami River and Biscayne Bay. These observations were made every half mile, starting out in the Atlantic, crossing the bay, and up the river as far as any mangroves extended, the data bearing on the distribution of *Rhizophora* in the Florida coast region. The water was taken both at the surface and on the bottom by the use of the deep-sea water-sampling apparatus designed by Dr. A. G. Mayer and used by the late Mr. Drew in his work on the bacterial content of the sea-water of the Florida Key region. The peculiar conditions of the overlapping strata of water near the mouth of the Miami River made these results most interesting. The same sort of observations were also made on Arch Creek, which likewise empties into Biscayne Bay.

Herbarium specimens of a number of noteworthy species and also material of *Rhizophora* for histologic study on the structure of leaves from plants growing in fresh water and those in salt water were collected in the vicinity of Miami. Live material of the Tillandsias growing on the mangroves as epiphytes was sent north for future study and cultivation in the greenhouses, as well as some young *Rhizophora* plants. On the upward trip, aboard the yacht, notes were taken and maps made of all the keys on which mangroves were lacking from Key West to Miami. As nearly all the Florida Keys support a luxuriant flora of mangroves, these maps note only the exceptions. The reasons for the lack of *Rhizophora* at these particular places will be given in a larger paper dealing with this research.

The author plans to continue the work in a future season, at a tropical laboratory, on the physiology of special cells in the plant's embryonic structure. Such work would require more abundant material and more rapid manipulation of the material than the Tortugas station affords. The hope is here expressed that the Institution will soon be supplied with a permanent tropical laboratory, so situated that botanical research similar in character and scope to that done at Buitenzorg, etc., may be pursued in this hemisphere under the Institution's auspices.

Report on Studies at Tobago, British West Indies, by Hubert Lyman Clark.

The abundance of echinoderms on the reefs near Pigeon Point, Tobago, made the location of the laboratory there an ideal one for me. My work developed along three lines, each of which gives promise of valuable results.

The discovery of a crinoid living in shallow water in Buccoo Bay, where it was common and easily accessible, enabled me to study the habits and reactions of a group not hitherto available for such study, for this crinoid, *Tropiometra carinata* (Lam.), belongs to a family of free-living forms (comatulids), so poorly represented at the Murray Islands, Torres Strait, that it was not included in the comatulid studies I made there at the Carnegie laboratory in 1913. I have thus been able to supplement those studies, and the results are of no little interest, *Tropiometra carinata* being a much hardier species than any hitherto observed. This hardiness was shown not

only by the ease with which specimens could be kept over night in small aquaria, but by their ability to withstand a wide range of temperature and an equally remarkable range of salinity. They also showed an indifference to bright light that was unexpected. The temperature range is well over 12° C.; it was not feasible to determine the minimum temperature, but the lowest observed was approximately 22°. Temperatures as high as 34° were not fatal unless prolonged; the critical point seems to be between 35° and 36°. It is possible, of course, even if not probable, that temperatures much below 22° would not be fatal. The salinity range was determined both by diluting normal sea-water with rain-water and by evaporation of sea-water at laboratory temperature to the desired concentration. Individuals survived 12 hours in sea-water so dilute (75 to 80 per cent normal) that their color was somewhat extracted, the water becoming distinctly yellow. On the other hand, water 10 per cent more saline than normal produced no apparent injurious effects in 12 hours, and 3 hours in water 20 per cent more saline than normal was not fatal.

A second line of work was connected with the accumulation of material to show growth-changes in young echinoderms. After the completion of the larval stage, which is usually passed swimming freely in the sea, most echinoderms assume quickly the adult form, but are of very minute size. The subsequent growth-changes throw a flood of light on phylogenetic history, but relatively little has yet been done in working them out. At the Pigeon Point laboratory I secured material showing more or less fully the growth-changes in 3 species of starfish, 9 species of brittle-stars, 1 sea-urchin, and 4 holothurians. Of course, in most of these the series of developing individuals is incomplete, but in at least three of the brittle-stars, one starfish, and one holothurian it is sufficient to yield results of great importance.

The third line of research was concerned with the composition of the echinoderm fauna of Tobago. During the 5 weeks we collected 75 species, of which about one-fifth seem to be new to science. Some of those which are not new are of even greater interest, either because their habitat has not previously been known or because their occurrence at Tobago is a notable extension of their range. It is my purpose to make a critical study of this Tobagoan fauna in comparison with that of Jamaica and the other West Indian islands, in the belief that such a study will throw light on the past history of the Caribbean region. It may be mentioned in passing that more than one-third of the species of echinoderms found at Tobago are not yet known from Jamaica.

On the Development of Some West Indian Echinoderms, by Th. Mortensen.

The time spent at the island of Tobago (March 23 to April 23) turned out to be very profitable for studying the development of echinoderms, a considerable percentage of the species being ripe at this season. The physical conditions were also unusually good, the oceanic currents that sweep round the island and the limestone formation of the south end of the island, where the laboratory of the expedition was established, both being important factors for producing the pure water so essential for rearing echinoderm larvæ. This, together with the unusual richness of the littoral echinoderm fauna, again the result of the physical conditions, accounts for the decided success the writer's efforts met. Ten different forms were studied, as follows:

Diadema antillarum	Tripneustes esculentus	Ophiothrix angulata, var. nov.
Echinometra lucunter	Mellita 6-perforata	
Ophionereis squamulosa	Amphiura sp. nov.[1]	Ophidiaster guildingii
Tropiometra carinata	Lytechinus variegatus	

[1] I am indebted to Dr. H. L. Clark for the specific names of these ophiuroids.

Of *Diadema* only the first larval stage was reached, the culture being accidently destroyed when a week old. All efforts to get a new culture started were in vain, the breeding-season of this species being then passed, although only a week before several specimens were still found containing ripe sexual products. *Tripneustes esculentus* and *Lytechinus variegatus* were raised until the beginning of metamorphosis, *Echinometra lucunter* and *Mellita 6-perforata* through the complete metamorphosis. The Mellita larva shows the structure typical of clypeastroid larva; the other larvæ all belong to the type with a posterior cross-rod in the final larval stage, the body skeleton in the first larval stage forming a frame. *Lytechinus* is, however, peculiar in that no frame is found in the first larval stage.

No other echinoids were found ripe during the time the expedition stayed at Tobago. Of asteroids, only one species, *Ophidiaster guildingii*, was found ripe, and that not until the very end of our stay, so that the fertilization could not be undertaken until 3 days before we left. Accordingly, only the very youngest larval stage was reached, but, nothing being known hitherto regarding the development of any of the Linckiidæ, the fact here discovered that this species has a typical bipinnaria larva is of interest.

For the ophiuroids, the season was rather too early, most of the species being unripe. Of 3 genera, however, the development could be studied, namely, *Ophiothrix*, *Ophionereis*, and *Amphiura*. The *Ophiothrix* larva closely resembles that of *Ophiothrix fragilis*, the skeleton being of the same type as in that larva. The *Ophionereis* larva, although free-swimming, does not assume the shape of a pluteus. It is worm-shaped, without any trace of a larval skeleton; the metamorphosis is completed in about 3 days. The *Amphiura* was found to be viviparous.

While the holothurians did not yield any results, the single crinoid occurring at Tobago, *Tropiometra carinata* proved to be a very favorable object for embryological study and its development is of more than usual interest. The eggs are not held on the pinnules, but dropped free into the water. The fertilization membrane is finely sculptured, closely set with small spines. The embryo, which has the same shape as the Antedon larva, swims very actively for a period of about 3 days, when it attaches itself; but if no suitable place of attachment is found, it may continue its free-swimming life, and in some cases it was found not to attach itself until it was 8 days old. The pentacrinoid and its growth-stages have not been studied in detail; reference must be made to the final report on the development of this crinoid, which will appear later. The full report on the other echinoderms studied during the expedition will be incorporated in the report on the studies on echinoderm development carried out during the winter's voyage in the Pacific regions in 1914–15.

Studies on Alcyonaria, by L. R. Cary.

The examination of specimens of several species of Alcyonaria growing on tiles, all of which were in relatively shallow water, showed that in many instances the growth had been only about 5 per cent annually for each of the past three years. The average size of specimens of the same species occurring on the reefs in depths of from 1 to 18 meters must necessitate either a very long period of growth, or else the growth must have been much more rapid than that shown by the specimens on the tiles. These facts were brought to my attention last season, when the deeper reefs were studied by the aid of diving apparatus. At that time an equal number of tiles with specimens of the same species of gorgonians were placed on a reef in water

1 meter in depth and another lot on a reef in water 6 meters deep. At the end of a period of one year the measurement of the specimens on these tiles showed that a considerably more rapid growth had been made by the specimens in the shallow water than by those at the greater depth. Since, from the nature of their immediate surroundings, it seemed probable that the food-supply of the specimens in deeper water might be less abundant than that of those on the shallower reef, the specimens from both locations were transferred to a reef at a depth of about 4 meters, where the conditions would be practically identical for each of the specimens. As specimens of each species of gorgonian as great in size as any of those on the reefs in deeper water could be found on all the reefs in this last-mentioned depth, it is apparent that the generally larger-sized deep-water gorgonian fauna depends on some factor other than depth alone. The fact that the greatest percentage of large specimens is to be found on the deeper reefs and on the lagoon side rather than on the Gulf side of most of the reefs points to greater protection from wave-action in time of storms as being the most important factor in determining the character of the alcyonarian fauna of any reef.

Studies on the Physiology of the Nervous System of Cassiopea xamachana, by L. R. Cary.

A. Influence of the Marginal Sense-Organs on Rate of Regeneration.

The results of my earlier studies[1] have shown a marked influence of the sense-organs on the rate of regeneration in *Cassiopea xamachana* Bigelow, when halves of the same individual disk were used for comparison. In the previous experiments the halves of each disk were insulated by removing two strips of subumbrella ectoderm (which contains the nerves and muscles) from opposite sides of the disk, while the regeneration was measured inward from the periphery of a cavity, where a circular piece of tissue had been removed from the central part of the disk. In all of the experiments carried out this season each disk was cut into halves and the regeneration was measured from the periphery of a cavity left by the removal of a circular piece of tissue 22 mm. in diameter that was cut from a corresponding part of each disk. By this procedure the difficulties in securing accurate measurements of the regenerating tissues, so frequently met with in my earlier experiments, were done away with.

Two series of experiments were carried out primarily to study the regeneration. The remaining observations on this question were made upon material used primarily for another problem (section B, below).

In the first series of experiments 3 sets of 40 disks each were divided into halves and the same operation performed on the halves of each disk. In one set all of the sense-organs were removed for both half-disks and a circuit wave of contraction maintained in a labyrinth of subumbrella tissue of both half-disks. In another set all sense-organs were removed from both halves and both of them allowed to remain inactive. In the third set a small piece of tissue was removed from between the sense-organs of each half-disk which retained its full quota of sense-organs. This extensive "control" series was undertaken to ascertain the limits of variation in the rates of regeneration shown by the two halves of the same disk under the conditions existing during the course of the regular experiments. The results from these experiments showed that, under either of the three operations mentioned, the

[1] Cary, L. R., Year Book Carnegie Institution of Washington, Nos. 13 and 14; Proc. Nat. Acad. Sci., vol. 1, No. 12; Jour. Exp. Zool., vol. 21, No. 1.

variations were in all instances less than the unit of measurement, so that any irregularities in the operations were not of sufficient magnitude to appreciably affect the results of any series of experiments.

As the influence of the rhopalia on the rate of generation is most marked in the earlier stages, a number of experiments were carried out to determine the effect of the removal of the rhopalia at different intervals of time after the original operation. The first operation consisted of the separation of each disk into halves and the removal of a disk of tissue 22 mm. in diameter from near the cut edge. The halves of each disk were kept in the same jar of sea-water and the rhopalia removed from one half at intervals after the operation, as shown in table 2.

TABLE 2.

Series No.	First operation.	Rhopalia removed.	Result.
1	$9^h 45^m$ a. m., July 22	7 a. m., July 23	Half with sense-organs fastest.
2	8 a. m., July 24	7 p. m., July 24	Do.
3	7 15 a. m., July 25	8 a. m., July 26	Regeneration equal.
4	8 a. m., July 25	4 p. m., July 25	Half with sense-organs fastest.
5	7 a. m., July 26	8 a. m., July 27	Regeneration equal.

All these experiments were carried on until the cavity had been closed by the regenerating tissue. In every instance a period of at least 24 hours from the time of the first operation was necessary in order that the rates of regeneration should be the same for the two halves of the disk. When the rhopalia were removed, in less than 24 hours from the time of the first operation, it was impossible to recognize any difference from the regular type of experiment in which the rhopalia were removed from one half-disk of each pair at the time of the beginning of an experiment.

In many of the experiments to determine the influence of the rhopalia on the loss of weight of starving and regenerating disks, a 22 mm. disk of tissue was removed from each half-disk and a record of the amount of regeneration was made at the time of the daily weighing of the specimens. The operations in these experiments were similar to those used in previous regeneration experiments and the results for regenerations were in perfect accord with those previously obtained.

B. Influence of the Rhopalia on the Loss of Weight in Regenerating Disks of Cassiopea.

Mayer[1] found that when a complete normal *Cassiopea* was starved in sea-water from which all food organisms had been removed by careful filtration the loss of weight could be expressed mathematically by the formula $y = W(1-a)x$, in which W equals the original weight, x the number of days of starvation, and a a constant, the "coefficient of negative metabolism."

As would be expected, the loss of weight of the disk alone does not correspond exactly to that for the entire medusa. The value of a in the equation given above differs in experiments involving varying conditions as regards light and darkness, presence or absence of regeneration, etc., but in all cases the above formula gives a very close approximation to the observed loss of weight.

[1] Mayer, A. G., The Law Governing the Loss of Weight in Starving Cassiopea; Publication No. 183, Carnegie Institution of Washington.

In my experiments the two halves of a series of disks were compared upon which there had been performed one of the three types of operations regularly used in the previous regeneration experiments. By means of these operations a comparison was made between the halves of a given disk, one of which retained its sense-organs, while these were removed from the other half (active and inactive series). In a second operation the rhopalia were removed from both half-disks, while one of them was activated by means of a circuit wave of contraction maintained in an endless labyrinth of subumbrella ectoderm (activated and inactive series). The third set consisted of disks one half of each with its sense-organs to control contraction, while the other half was activated by a circuit wave of contractions in its subumbrella muscles.

In the first type of experiment the loss was always greater for the half with its sense-organs than for the inactive half, as shown in table 3.

TABLE 3.—*Differences in loss of weight in active and inactive half-disks.*

Days after operation.	Weight of half with sense-organs.	Weight of half without sense-organs.
0	100	100
1	75.34	81.81
2	66 72	71.27
3	58.54	64.09
4	55.27	55.41

The weights given in tables 3, 4, and 5 are reduced to terms of 100 grams at the beginning of the experiments.

As will be noted, for each set of half-disks the loss is greatest for the first day and becomes progressively less throughout the experiment. The actual difference in the amount of the loss becomes very much less as the experiment is prolonged until at the fourth day after the operation both halves have lost approximately 55 per cent. Both of these features of the results resemble very closely those obtained in regeneration experiments. Thus the sense-organs appear to affect the loss of weight in much the same manner that they do the rate of regeneration, at least a graphic expression of the results obtained by the two methods are closely similar to one another. These results support my previously expressed views that the rate of regeneration is one expression of the general metabolism of the medusa, and as such is under the influence of the nerve-centers.

When a comparison is made between the rates of loss of half-disks with sense-organs and those activated by a circuit wave of contraction, as shown in table 3, it is seen that the activated half-disk loses weight to a considerably less extent than does the half with sense-organs.

On the other hand, the muscular activity of the activated half-disk was never less than three times that of the half with sense-organs. As the experiments progressed, the difference in the rate of pulsation constantly became greater. The rate of the half-disks with sense-organs usually fell, within 24 hours from the time of operation, to less than half the rate immediately after the operation; on the contrary, there was commonly an increase in the rate of pulsation of the activated half within the first 24 hours, after which it remained practically constant. In the third, fourth, and fifth days of any experiment the pulsation-rate of the activated half of any pair of half-disks was frequently more than ten times the rate of the other half of the same disk upon which the sense-organs remained.

In order to determine as accurately as possible the relative amounts of muscular work performed by the two half-disks under the conditions of this type of experiment, simultaneous kymograph records were made from the two halves of the same disk which had been operated on in the manner described. If no cuts were made in the subumbrella tissues of the half-disk with sense-organs, its pulsations were registered on the kymograph as of about three times the amplitude of those of the activated half-disk. When, however, the cuts necessary to form a labyrinth of the subumbrella tissue similar to that in which the circuit wave of contraction was maintained in the activated half were made in the disk with sense-organs, the amplitude of the contractions was no longer greater for the half-disk with sense-organs attached. The striking visual difference in the extent of contraction is therefore due to the ability of the undisturbed sheet of muscle to cause the margin of the disk to fold inward in contraction in a normal half-disk, giving the regular swimming movement, while the cuts necessary to form the labyrinth of subumbrella tissue essential for the maintenance of the circuit wave of contraction breaks the continuity of this sheet of muscles and makes impossible the folding over of the margin of the disk, which gives the appearance of greater vigor to the pulsation of the uncut disk. When the two half-disks have been subjected to the same type of operation, except that the rhopalia have not been removed from one half, the amplitudes of contraction are registered as of equal extent, so that the pulsation-rate is, therefore, a true index of the amount of muscular work done.

A comparison of the loss of weight between activated and inactive half-disks, given in table 4, shows that the differences in the rate of loss are relatively small, although the activated disks were undergoing great muscular activity.

TABLE 4.—*Differences in loss of weight between active and activated half-disks.*

Days after operation.	Weight of half with sense-organs.	Weight of activated half.
0	100	100
1	76 29	79 41
2	67 18	70 58
3	59 76	61 99
4	55 58	57 18

TABLE 5.—*Differences in loss of weight between activated and inactive half-disks.*

Days after operation.	Weight of activated half.	Weight of inactive half.
0	100	100
1	79 47	81 97
2	70 63	71 48
3	62 03	63 91
4	57 21	57 23

The two last-mentioned experiments indicate very clearly that muscular activity, even when greater than normal, is a relatively small factor in the metabolism of *Cassiopea*, thus confirming the conclusions drawn from the study of the rates of regeneration under similar experimental conditions.

In connection with the experiments in which both the rates of regeneration and the loss of weight were observed for two series of 40 half-disks each, another series of measurements was made, the results of which support the conclusions drawn from the two just mentioned. When the half-disks were prepared for the regeneration measurements a circular disk of tissue 22 mm. in diameter was removed from each half-disk. The diameter of the cavity left when this disk was removed, when measured daily, was found to have decreased in diameter more rapidly in the specimens bearing sense-organs, less rapidly in the inactive specimens, and to only a slightly greater extent in the activated specimens than in those which were inactive.

C. The Influence of the Sense-Organs on the Total Metabolism, as Measured by CO_2 Production in Cassiopea.

Continuing the experiments started last season in collaboration with Dr. S. Tashiro,[1] a series of determinations was made of the total amount of CO_2 produced by the separate halves of a medusa disk, one of which was pulsating under the influence of its sense-organs, while the other was activated in the manner previously described for regenerations and starvation experiments. The comparison of the halves of 50 disks was made in this manner, with results which confirm those previously obtained, namely, that the half-disk pulsating more slowly under the influence of its sense-organs produces as much CO_2 as the more rapidly pulsating activated half.

As pointed out on pages 195–196, the rate of pulsation is a true measure of muscular work done when a labyrinth of subumbrella tissue has been formed on each of the half-disks. The results of this series of experiments, therefore, are completely in accord with those obtained from experiments dealing with the influence of the sense-organs upon the rate of regeneration and the loss of weight during starvation.

As the greater number of these experiments were allowed to continue until one of the half-disks of a pair has ceased to pulsate under the narcotizing effects of the CO_2, it was possible to secure a measure of the CO_2 concentration necessary to bring about narcosis. In nearly all instances the activated half-disk was the first to succumb, and once it had stopped it could not start pulsating again until stimulated by an induction shock. The half-disks with sense-organs showed more resistance to CO_2, and when removed from the closed jars where they had ceased to pulsate and put into fresh sea-water, they would start pulsating again within 1 to 2 minutes, even when they had been inactive for several hours.

Throughout these experiments the records of CO_2 production were made in terms of increased hydrogen-ion concentration of the sea-water in the closed jars, and up to the time this report was written not all the necessary data had been secured to complete a curve to show the amount of CO_2 necessary to bring about a given change in the hydrogen-ion concentration of the unit volume (1,250 c.c.) of sea-water used in the experiments. This phase of the work is being completed at the Biological Laboratory at Princeton University.

D. The Changes in the Rate of Nerve-Conduction in Cassiopea in Response to Change in Temperature.

The experiments upon this subject were undertaken primarily to determine the response of the sense-organs to changes in temperature. Mayer[2] has shown that the initiation within the sense-organs of the stimulus for normal pulsation is a relatively simple chemical reaction. It was therefore thought possible that if a single sense-organ with only a narrow band of tissue connecting it to the remainder of the disk was subjected to changes in temperature, while the remainder of the disk was kept at a constant temperature, the change in the rate of pulsation might follow Van't Hoff's law more closely than other measurable biological processes have been found to do. It was ascertained, however, that even in water of constant temperature the rate of pulsation of a disk ennervated by a single sense-organ varied too widely within the time covered by one of these experiments to give any conclusive results.

[1]Year Book No. 14, Carnegie Institution of Washington.
[2]Mayer, A. G., on Rhythmical Pulsation in Scyphomedusa, Carnegie Inst. Wash. Pub. No. 102.

The remaining experiments on the response to changes in temperature were carried out to obtain a comparison of the response to changes of temperature of the two halves of a disk, one of which retained its sense-organs, while the other was activated by a circuit wave of contraction. As a general statement of the results, not all the data of which have as yet been reduced to graphic form, it may be said that for an increase of 10° C. from 23° to 33° the pulsation-rate of the activated disk was approximately doubled. Beyond a temperature of 35° there was a rapid decline in the rate, pulsation ceasing at about 40°. The curve for this increase was up to 35° a right line, not a logarithmic curve, as would be true for a purely chemical reaction.

The rate for the half-disk with sense-organs reached its maximum from 27° to 29° and then slowly declined until pulsation ceased at about 40°. These specimens, if cooled slowly, took up pulsation again at about 37°, and in several instances were kept alive for a number of days after the experiment. The change in rate was often very erratic in specimens with sense-organs, and the maxima varied from 1.3 to 6 times the original rate.

E. The Relation Between the Area of Tissue Ennervated by a Single Sense-Organ and the Rate of Pulsation.

The study of a large series of disks under the control of a single sense-organ has shown that there is a regular decline in the rate of pulsation as the tissue area is reduced until when the area is one-sixteenth that of the original area the rate of pulsation is one-half that of the entire disk.[1] This research was continued during the present season in the hope of securing some evidence as to the nature of the factors determining this reduction in the rate of pulsation. It was found that when the area of tissue was reduced to $\frac{1}{18}$ of the original size the muscles and nerves were still capable of responding to induction shocks at the rate of 120 per minute. There is, then, apparently no need for a latent period on the part of the muscle-tissue. When the area of the muscle-tissue under the control of the single sense-organ was reduced by putting a part of it into 0.4 m. $MgCl_2$ the rate of pulsation was reduced to the same extent as when an equal amount of tissue was removed by severing the muscles and nerves. This was true when the anesthetized tissue was in the middle of the strip as well as when it was at the end opposite to the sense-organ.

This result would indicate that the area of active muscle was the determining factor since the nerves were still capable of transmitting the stimulus for contraction as is shown when the narcotized area is in the middle of the strip of tissue.

Experiment on the Feralization of the Albino Rat, by Henry H. Donaldson.

In relation to the body-weight, the brain of the albino rat is about 12 per cent lighter than that of the wild Norway rat, from which this albino has been derived.

There was some reason to think that this character of the albino was due to the influence of domestication, and I wished therefore to establish a colony of these animals under conditions which would permit them to live in a wild state, in order to determine whether the relative weight of the brain would in successive generations return to that characteristic for the wild Norway.

In June 1914 Dr. Mayer placed on East Key in the Tortugas, Florida, 8 albinos (4 males and 4 females) which were sent from Wistar Institute. The rats were about 90 days old when released, but unfortunately were not ear-marked.

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[1] Cary, L. R., Year Book No. 14, Carnegie Institution of Washington.

Early in the spring of 1915 a passing fisherman reported white rats on East Key. In the summer of 1915 four were caught with spring traps, just to make certain that the rats were there. In May 1916 one was taken in a spring trap. It was preserved in formalin and subsequent examination showed that it was an animal of good size, but with infected lungs. At the invitation of Dr. Mayer, Dr. Hatai and myself went to the Tortugas Station in June of this year (1916) to make a study of the rats on East Key. One female was caught by us. There were fetuses at the 10-day stage in the uterus. This indicated the presence of a surviving male, but our efforts to trap more rats failed. When it became evident that the number of rats on East Key must be very small, a fresh lot of animals was sent to the Tortugas Station from the Wistar Institute. From this lot, which came through with only one death, 30 pairs were placed on East Key and 11 males and 13 females on Garden Key. Both groups were ear-marked. Ten days after their release albinos were observed on both of these keys, and no dead were seen. These two groups will be studied during another season.

East Key is oval in shape and about 300 yards long, and is moderately covered with brush. There is no fresh water to be obtained, except from rain and dew. The available food is mainly furnished by the sea oat and other grasses, the Ocypoda crab, and materials washed ashore. Our results show that under these conditions the albino rat is able to persist on East Key for a trifle over 2 years, and that the last one caught was pregnant. If no new litters had been reared during the two years' interval, then we have caught in all 6 out of the original 8 rats, and at least 1 male must have remained uncaught. The eighth animal is not accounted for.

The one female which was caught on East Key after our arrival at the Tortugas Station showed normal bodily proportions and had a weight of brain and of spinal cord almost precisely that to be expected in an animal of this size. However, we can not say whether this rat belonged to the original lot or whether she was bred on the Key.

The influence of the wild life would be expected to show only in the descendants, so that several generations will be required to determine whether a change has been effected. The lot brought to the Tortugas from Philadelphia this year was decidedly affected by the journey of four days, the relative weights of several of the important viscera and glands being much modified. In every animal examined the spleen was from two to three times its normal size; the percentage of water in the nervous system was also increased; but within ten days after their arrival at the Tortugas, rats which had been kept under favorable conditions in the laboratory showed a return of the modified organs to the normal relations.

It is to be noted that the house rat (*Mus alexandrinus*) lives under the Tortugas conditions and is found on Garden Key, Bird Key, and Loggerhead Key, having been brought by ships. In earlier years it was present in large numbers on Loggerhead Key. As *Mus alexandrinus* does not cross with the albino of *Mus norvegicus*, the presence of the former is not regarded as a disturbing factor for the present experiment.

Experimental Studies upon the Aging and Death of Germ-Cells, by A. J. Goldfarb.

Last year's studies with the sea-urchin, *Toxopneustes variegatus*, showed that certain profound alterations take place with increasing staleness of eggs and sperm. These changes may conveniently be grouped under three headings: (1) a lowered percentage of eggs capable of being fertilized; (2) a modified rate and a change in the character of the fertilization membrane; (3) a

lowered percentage of eggs that cleaved, and a change in their development. These results suggested that other factors connected with over-ripening of germ-cells be studied with a view towards obtaining a more adequate chemico-physical explanation of the phenomena associated with the aging and death of germ-cells. As the inquiry extended, it was found increasingly desirable to concentrate upon the changes in the egg alone, and to postpone for a later opportunity the more detailed study of the sperm-cell. The sea-urchin *Hipponoë* was used for this summer's work at Tortugas, Florida.

The investigation extended principally along five lines, namely: (1) changes in the jelly envelope; (2) changes in volume of the egg; (3) effects of temperature; (4) changes in the cortical layer; (5) respiration of aging eggs.

Changes in the Jelly Envelope.

Eggs freshly shed or removed from the body were nearly always surrounded by a thick hyaline envelope, which was made strikingly clear by Chinese-ink solution. At successive intervals the eggs kept in bowls of sea-water just below room temperature lost the jelly envelope more and more completely, and the extent and rate of disappearance was ascertained. It was found that in the beginning there was little or no disappearance of the jelly, followed by a period of rapid dissolution, and finally, all, or very nearly all, the eggs were without their jelly coating. These three parts of the curve may serve as convenient though general indices of the condition of the germ-cells and indicate the period of ripeness, dying, and death of the eggs. This statement applies only to such eggs whose jelly had not been removed by mechanical or chemical means.

Changes in Volume.

When the eggs of any female were carefully measured at different intervals and the results plotted, the curve showed at least three points of special interest. First, there was an initial period without change in the volume of the eggs. This was followed by an unmistakable and continued increase in size, followed by a third period during which, partly by budding off of particles of the egg-cytoplasm and partly by fragmentation, and in extreme cases more or less complete disintegration, the egg became decidedly smaller, even smaller than its original size. These three parts of the curve correspond with the three parts of the curve representing the disappearance of the egg-jelly. And these three parts of the curve are associated with periods of little or no aging, of rapid aging, and of the death of the eggs. This curve of volumetric changes may be used as a much more accurate measure of the rate and the extent of the effect of aging upon the egg than can the curve for the egg-jelly.

Effect of Temperature.

If the processes involved in the aging and dying of eggs are chemico-physical in their nature, we should anticipate that Van't Hoff's law of the proportionate increase in activity with a given change in temperature would hold for the processes involved in aging eggs, and that the longevity was proportional to the temperature at which the eggs were kept.

The outline of a typical experiment may serve to make the matter clear. Eggs of a female were kept in aliquot parts in several dishes of the same type and size and with the same quantity of sea-water. One half of the dishes were kept at a temperature, nearly constant, of 10° C., the other half at a temperature of 27° to 29° C. At intervals the eggs were tested with fresh sperm and the percentage of eggs that were fertilized in each batch was compared and used as a measure of the differential mortality. The Van't Hoff expectation was very closely realized.

Changes in the Cortical Layer.

When eggs became stale a number of changes took place simultaneously, namely, loss of egg-jelly, increase in the size of the egg, absence of fertilization membrane, gelatinization of the cortical layer of the egg, etc. These changes are explicable in terms of a chemical change which causes the outer layers of the egg to be dissolved and which changes the permeability of the cortical layer with a consequent intake of sea-water. The aging process proper corresponds with the period of changed permeability, and it may be experimentally shortened by hypertonic solutions of sea-water.

An examination of the sea-water at the Tortugas disclosed the fact that when tested by colorimetric methods as well as by the electric potentiometer, which determinations were made by Professor McClendon, the hydrogen concentration of the sea-water was PH 8.1 to 8.2. It is this relatively large excess of free hydroxyl-ions in the sea-water which is responsible for (1) the dissolution of the egg-jelly, (2) the changes in the cortical layer with the consequent intake of water, and (3) the accelerated respiration that takes place in aging eggs; and, if this assumption be correct, it follows that with an increase of the free hydrogen-ion concentration to the neutral point these deleterious changes would be retarded or minimized or possibly prevented and the longevity of the egg correspondingly increased; conversely, in hyperalkaline solutions of sea-water the mortality would be accelerated.

Many experiments were made along these lines. At different intervals the eggs in the following solutions were tested, namely: in sea-water, in sea-water made neutral, sea-water made slightly acid, sea-water made hyperalkaline. A number of errors in these experiments were later corrected in experiments with *Arbacia* at Woods Hole, but the general results are clear and in striking accord with expectation. Eggs kept in neutralized sea-water were longer-lived than control eggs and showed less developmental irregularities than the controls, and longevity was decreased with hyperalkaline solutions.

Respiration of Aging Eggs.

With the aid of a manometer suggested by Professor McClendon, and which gave direct readings of the oxygen consumption, it was possible to obtain continuous readings of the respiration of a sample of eggs from the time of shedding to the death of the unfertilized eggs. Corresponding records were obtained for the fertilized eggs. The data were plotted and showed for the unfertilized eggs a gradual increment in the oxygen consumption for the first 5 to 6 hours, then a plateau for 2 hours, during which time respiration is maintained at a uniform rate, and then a sharp rise in the rate of oxidation. The last part of the curve continues till all the eggs are disintegrated. The curve so obtained is parallel with the curves for egg-jelly dissolution and the curve for increase in volume with age, and it serves as another and parallel index of the rate and measure of the aging process in eggs. The sharp rise in oxygen consumption occurs when the jelly is dissolved completely from all or nearly all the eggs, when the cortical layer is permeable to sea-water and enlargement has taken place, and when death of the eggs is rapidly taking place.

These studies have thrown light upon the nature of the changes that take place when eggs become increasingly stale, and they indicate how aging may be prevented, either by retarding the respiratory rate, as Loeb has so beautifully demonstrated, or by preventing the dissolution of the cortical layer of the egg, as I have merely outlined in this summary.

Report on the Chemistry and Physiology of some Luminous Animals of Japan, by E. Newton Harvey.

During a period of three months the author studied in detail four luminous forms—a squid (*Watasenia scintillans*), an ostracod crustacean (*Cypridina hilgendorfii*), a pennatulid (*Cavernularia haberi*), and the Japanese fireflies (*Luciola parva* and *L. vitticollis*). The protozoon *Noctiluca miliaris*, unusually abundant about Japan, was studied by Mrs. Harvey, especially as to light-production and anesthesia. Observations were also made on the luminescence of a fish (*Monocentris japonica*), the lantern squid (*Inioteuthis inioteuthis*), two hydroids (*Sertularia* sp. and *Campanularia* sp.), and *Pennatula* sp. *Monocentris japonica* is of interest because the light, which comes from two small organs on the lower jaw, is steady and continuous, and not, as in most fishes, a series of flashes, the result of stimulation. This fish, *Pennatula*, and the five first-mentioned forms all give light if brought from daylight to darkness, a condition quite different from that observed by Peters in the ctenophores.

Watasenia scintillans is caught in enormous numbers by the fishermen of Toyama Bay on the northwest coast of Japan during April, May, and June. The light from the tentacle organs is a brilliant bluish color, fully as intense as that of the firefly; hence the Japanese name, "firefly squid" or "hotaru-ika." The animal is a deep-sea form which comes to the surface to breed; it is consequently exceedingly sensitive and has proved to be of little value for chemical research.

Cavernularia haberi colonies contain a network of nerves connected with the light-producing cells, and a brilliant wave of light passes over the colony in every direction from the point stimulated. The light-wave will also pass a cut completely isolating the surface epithelium and must be conducted by inner tissues. The light comes from small granules in the fluid expressed by pressure from the colony. This fluid glows for several hours spontaneously and upon the addition of water will glow even after two days. The light substance can not be preserved except by rapid drying, and in every way is very unstable and quite different from that of *Cypridina*, described below. The granules will not pass a Chamberlain porcelain filter.

The light-substance of the firefly approaches *Cypridina* in properties, but is more unstable and can be preserved for any length of time only in the dry state. Space does not permit a discussion of the firefly apart from *Cypridina*.

Cypridina hilgendorfii offers exceptional opportunities, as it contains a large amount of luminous material giving a brilliant bluish light—a substance so powerful that it may be detected in at least a concentration of one part in 1,600,000,000 parts of water. Could this material be synthetized, there is no doubt of its efficiency for illuminating purposes.

As first shown by Dubois in 1885 for *Pyrophorus noctilucans* and in 1886 for *Pholas dactylus*, there occur also in *Cypridina* two substances, separable by heat, luciferin and luciferase (Dubois), which must be mixed, together with water and oxygen, before light will appear. Each alone in solution is non-luminous. This reaction is also given by the firefly (both Japanese and American species), but not by *Watasenia, Cavernularia, Pennatula,* or *Noctiluca*, despite the most favorable conditions.

The evidence from *Cypridina* shows, however, that Dubois's theory of the mechanism of light-production is incorrect. Luciferase, the thermolabile substance, is the source of the light, and not luciferin, the thermostabile substance, as Dubois supposed. The new names of photogenin (light producer) for luciferase and photophelein (light assister) for luciferin have therefore been proposed to indicate more truthfully the nature of light pro-

duction. The preparation of photogenin and photophelein is described in my paper in *Science* (n. s., XLIV, 652.) Contrary to Dubois's results for *Pholas*, I find photogenin (luciferase) only in the light organs of luminous animals and photophelein (luciferin) widely distributed in the animal kingdom. In the case of *Cypridina*, photogenin is a very stable substance and may be preserved in solution for over 56 days with chloroform. In the case of the firefly and *Pholas* photophelein is the more stable substance.

Photophelein and photogenin are both adsorbed by animal charcoal or $Fe(OH)_3$, but will easily pass a Pasteur-Chamberlain porcelain filter. Photophelein dialyzes easily, photogenin only with extreme difficulty. The reaction between photophelein and photogenin is not specific, although photogenin gives a better light with photophelein from the same species than from other luminous species. Neither photogenin nor photophelein are true enzymes, although the photogenin from one *Cypridina* will use up the photophelein from at least 100 others.

The photogenin and photophelein of *Cypridina* are secreted together into the sea-water as a perfectly clear granule-free secretion from gland cells on the upper lip, but as already mentioned, in the body, photophelein is found throughout the animal, probably in the blood; photogenin only in the luminous cells. Just as in the presence of photogenin, photophelein is rapidly used up with light-production, so in the presence of the extract of the non-luminous cells of *Cypridina*, photophelein quickly disappears but without light-production. If we boil the non-luminous cell extract or exclude oxygen, the photophelein is not so rapidly used up. In the case of the firefly, the photophelein disappears so rapidly from an extract of non-luminous cells that it is necessary to extract them with boiling water to prepare a stable solution giving light with photogenin. Because of failure to boil the extract, I previously had overlooked the existence of photophelein in the non-luminous parts of fireflies. The evidence seems to indicate that boiling destroys a substance existing in the non-luminous parts which oxidizes the photophelein.

Further facts concerning the properties and the effects of temperature, acids and alkalies, protein coagulants, anesthetics, etc., on photophelein and photogenin, as well as a discussion of the theory of Dubois and my own, will be found in my complete papers on *Cypridina*, *Cavernularia*, and the firefly, and Mrs. Harvey's paper on *Noctiluca*. A fact of considerable interest is the comparative harmlessness of KCN, which has no effect on light production, although this process is an oxidation in all forms.

Regarding the chemical nature of photogenin, nothing definite can as yet be said, except that it is not a fat or fat-like body, but is probably protein. *Cypridina* is an excellent form for such investigation, and I expect to report more definitely concerning photogenin in the near future. *Photoblepharon*, a surface fish of the East Indies, whose large light-organs glow for many hours even when excised, seems also highly favorable for chemical work.

The present work can be considered only as a beginning, and opens up a large field for future study. There are many organisms as yet almost wholly uninvestigated, and those forms which have been investigated, if we may rely upon the statements recorded, differ in such very essential points that we may perhaps look to several distinct methods of light production. The production of colored light and the distribution of photogenin and photophelein among luminous animals offer problems of fascinating interest.

In conclusion, I wish to express my sincerest thanks to my Japanese friends, particularly to Professor C. Ishikawa, of the Agricultural College, Imperial University of Tokyo, for his interest and assistance, and to Professor Ijima, of the Zoology Department, Imperial University of Tokyo, for the hospitality of the Marine Biological Station at Misaki. I am also greatly

indebted to Dean Kozai and Professor Aso, of the agricultural college, for the use of chemicals and apparatus, without which many of the experiments could not have been performed. The amount of work which I was able to accomplish was largely due to Mrs. Harvey, who made observations of the results of many of my own experiments during a temporary strain of my eyes.

Changes in the Chemical Composition of Starving Cassiopea xamachana (Preliminary Report), by S. Hatai.

Mayer (1914) found that in *Cassiopea* the percentage of nitrogen to its dried weight is constant during the entire period of starvation. Mayer infers from this that "no appreciable chemical change occurs in the composition of its body-substances, and there is no appreciable selective use of different substances at different times during the progress of starvation." This is remarkable, since the starving mammalian body reveals a totally different relation, owing to the rapid disappearance of reserve substances, such as carbohydrates and fats, at an earlier period of starvation, followed by a consumption of protein substances at a somewhat slower rate. In other words, the starving mammalian body gives different percentage values of total nitrogen at different periods of starvation, especially in its earlier stages.

The anatomy of the medusa in general suggests that since a greater fraction of the body is represented by the reserve jelly-like substance, while the amount of living cellular elements is negligibly small, a constancy of nitrogen may mean that practically all the nitrogen is here represented by that of the jelly-like substance, thus totally masking those chemical changes which occur within the living cell elements. To test this point, the following experiments have been undertaken:

As a first step, I have attempted to clear up the following points:

(1) The normal decline in weight of different parts of *Cassiopea.* For this purpose the *Cassiopea* was divided into three different parts—mouth-arms, velar lobes, and umbrella. The object was to determine whether the starving *Cassiopea* loses weight uniformly in all parts of the body or whether the loss is dissimilar in these three parts.

(2) Percentage of water in these three parts. This was carefully studied, using the normal *Cassiopea* as a check. In addition, the water-content of the entire body of the normal *Cassiopea* of various sizes was also determined. The object of these determinations was to obtain some general information to be used for interpreting the chemical alterations following starvation.

At the same time, 8 examples of *Cassiopea* of various sizes (29 to 152 grams) were subjected to a complete starvation. The method of starvation and that of weighing were similar to those first used by Dr. Mayer (1914). At the end of 21 days of starvation, each *Cassiopea* was divided into three parts (mouth-arms, velar lobes, and umbrella), and each part was weighed carefully and then dried at 98° C. to a constant weight for the determination of water-content.

Since the work is still in process, I am unable to present definite conclusions, but can make the following very general statements:

(1) The water-content of the normal *Cassiopea* is practically constant in all sizes of animals examined (0.098 to 250 grams). The average percentage of water is 94.27 per cent. The constancy of water-content appears to indicate that the body of *Cassiopea* is largely composed of the jelly-like substance, the composition of which remains nearly identical throughout the animal's life-cycle. This is a remarkable contrast to the water-content of mammalian bodies of various ages, in which the younger individual gives a higher percentage of water, and *vice versa.*

(2) The water-content of different parts of the body is practically identical. This seems to indicate homogeneity of chemical make-up of the body, which in turn shows a low degree of chemical differentiation, despite the fact of a high morphological differentiation of the different parts of the body.

(3) The relative weight of the three different parts of the body varies according to the absolute weight of the *Cassiopea.* In other words, these different parts show dissimilar rates of growth, and it is hoped to find some suitable mathematical formula representing the growth curves of these parts to assist us not only in studying the phases of growth, but in comparing the results obtained for the normal with those of the starved *Cassiopea.*

(4) Cassiopeas starved for 21 days showed a reduction of body-weight from 62 per cent to 80 per cent, so that the resulting weights were only from 38 per cent to 20 per cent of the original. In general, the smaller *Cassiopea* lost relatively a much greater amount of weight than did the larger animal. In the starved *Cassiopea* the relative weights of the three parts coincides with those given by the normal *Cassiopea,* which has a body-weight similar to the starved *Cassiopea* at the end of the test, and not to the relative weights at the beginning of the experiment. This is highly interesting, since the starved *Cassiopea* by some process of readjustment seems thus capable of maintaining proportional weights which are normal for its absolute weight at any time. So far as the percentage of water in the different parts is concerned, the starved *Cassiopea,* like the normal animal, shows a like percentage in all three parts.

The dried materials obtained from these normal and starved *Cassiopea* are to be further analyzed in the near future.

Experiments with Tortugas Sea-water, by J. F. McClendon.

The true alkalinity of sea-water is expressed as PH (—log hydrogen-ion concentration). The PH of sea-water within 8 miles of Loggerhead Key, from the surface to a depth of 35 meters, varies from 8.1 to 8.22. The CO_2 tension of this sea-water is about 0.04 per cent of an atmosphere. A conversion table was made, from which the CO_2 tension and the total CO_2 content of the sea-water may be read after the PH and temperature are determined. Tubes colored with thymolsulphonephthalein were standardized by the hydrogen electrode, so that the PH of sea-water may be determined by the simple addition of this indicator, which can be easily done aboard ship in any kind of weather. These tubes show the true alkalinity, the CO_2 tension, and the total CO_2 content of the sea-water simultaneously. Sea-water was titrated with acid, using the hydrogen electrode as indicator, and the results agree with those of Dole's titrations "after boiling."

Distilled water requires at least 72 hours' aeration before it can be successfully used in making artificial sea-water; hence the substitution of rain-water is recommended. A close imitation of Tortugas sea-water may be prepared as follows (Steiger's analysis):

	From 1 normal solutions			From isotonic solutions		
$CaCl_2$	0.5 mol	22.07 c.c.	or	0.38 mol.	29.0 c.c.	
$MgCl_2$	0.5 mol.	50.21		0.37 mol.	67.9	
$MgSO_4$	0.5 mol	57.09		0.975 mol.	29.5	After mixing,
KCl	1.0 mol.	10.23		0.577 mol.	17.7	aerate until the
NaCl	1.0 mol	483.65		0.568 mol.	852.0	PH = about 8.15
NaBr	1.0 mol.	0.8		0.565 mol	1.4	
$NaHCO_3$	1.0 mol.	2.32		0.93 mol.	2.5	
H_2O		373.63				
		1,000.00			1,000.0	

It is necessary to add the alkali as bicarbonate, in order to avoid precipitation of $MgCO_3$ and $CaCO_3$, but after the mixture is made air must be bubbled through it rapidly for 6 hours, and longer if the rate is slow, in order to remove part of the CO_2 resulting from the dissociation of the bicarbonate, and thus obtain the correct hydrogen-ion concentration. In table 6 is given the approximate concentration of some minor constituents of natural sea-water and their probable concentration in artificial sea-water made from "analyzed" or "chemically pure" salts in parts per million. This estimate is confirmed by the fact that further recrystallization of the salts in pyrex glass did not improve the artificial sea-water. Artificial sea-water made according to this formula was satisfactory for animals. Plants require PO_4 and NO_3 or NH_3, but 1 NH_3 or 250 NO_3 per million is toxic to some algæ (but not to some diatoms), whereas animals with symbiotic algæ were affected by 5 PO_4 per million.

TABLE 6.

Substance.	Natural.	Artificial.	Substance.	Natural.	Artificial.
Fe.	1.0	0 2	NH_3....	0 01	+
I.	1 0	0 05	Zn	0.002	.
NO_3....	0 1	0 001	Pb.....	0.1	+
PO_4	1.0	0 003	Cu	0 01	..
SiO_2....	1.0	0 3	Ag	0 01	
As..	0 05	0.05	Au	0 01	.
Al_2O_3...	0.1	0.03	F	0 5	.

In previous papers I have shown that certain ions of sea-water increase the permeability of cells and that this change is inhibited by the other ions. This year's experiments on *Cassiopea* and the heart of the conch indicate that OH^-, Na^+, and K^+ increase the permeability and that H^+, Ca^{++}, and Mg^{++} inhibit their action. It should therefore be possible to find a protective solution for one cell structure containing only two of these ions in a balanced ratio. The fact that attempts to do this have failed indicates that each cell (of those thoroughly investigated) is composed of more than one structure with a characteristic optimum ratio for each pair of antagonistic ions. It is important, therefore, to intensively study very special phenomena, as Dr. Mayer has done in regard to nerve-conduction, in order to collect data for an analysis of the phenomenon of antagonism.

It has long been known that a nerve of the conventional nerve-muscle preparation may be stimulated electrically by less current if it is sent longitudinally through the nerve than if it is sent crosswise; but the explanations of this fact have not been in accord with recent work on the phenomenon of stimulation. Since the nerves that have been used were medullated, I repeated this experiment on the non-medullated nerves of *Limulus* and found that they were stimulated crosswise by as little current as was found to be the minimum for stimulation lengthwise (the electrodes being the same distance apart in each case). Therefore, the medullary sheath seems to inhibit cross-stimulation. Probably the medullary sheath is an insulator. The electrical conductivity of nerve is greater lengthwise then crosswise. Perhaps the alternating current running lengthwise between the nerve-fibers induces currents inside the medullary sheaths; or the current may enter and leave only at nodes of Ranvier and the poor result of cross-stimulation may be due to the small number of these nodes between the electrodes, unless the length of nerve affected is increased by spreading of the current (as is the case when stronger currents are used).

The Significance of the Colors of Tropical Reef Fishes, by W. H. Longley.

The months of June and July 1916 were spent at Tortugas in continued investigation of the colors and color-changes of reef fishes.

Three things were attempted: first, to obtain from nature submarine photographs of some of the fishes whose changes in color and shade depend upon the character of their environment; second, to ascertain the food and time of feeding of as many species as it might be convenient to examine; third, to determine to what extent green color is correlated with the habit of living upon reef flats covered with turtle grass (*Thalassia testudinum*). Incidental observations were also made which supplement those of other seasons. For example, an additional labrid (*Xyricthys* sp.) has proven to have the same interesting habit of burying itself in the sand at night that has been described for *Iridio* and *Thalassoma;* and, besides 8 already reported, adaptive color-changes have been noted in the following species: *Epinephelus striatus, Neomœnis griseus, Scorpœna plumieri, Siphostoma mackayi,* and *Sparisoma hoplomystax.*

As the photography was attempted under novel conditions, and the possibility of obtaining positive results could be determined only by experiment, much of the effort expended bore no immediate fruit. Some prints were secured, however, which show that many of the most striking facts regarding change in the pattern and shade of fishes in their normal habitat may eventually be presented pictorially.

The camera used was a Folmer and Schwing No. 0 Graphic, which takes a picture $2\frac{3}{8}$ by $1\frac{1}{2}$ inches in size. It was inclosed in a water-tight brass box having plate-glass windows in the front and rear, and above. Necessary adjustments of film, shutter, etc., were effected by screws guarded by flax and grease packing. In every essential respect this apparatus was satisfactory, for objects could be readily located in the finder, and a dozen exposures could be made without sending it to the surface to be opened and reloaded. It may be added, for the benefit of any who might think of attempting similar studies, that one should avoid having the photographic apparatus much heavier than the water it displaces. Additional weight interferes with ease and rapidity of movement and multiplies the labor of holding the camera in one position until the fish to be photographed appears to advantage.

No good pictures were taken at depths exceeding 12 feet, but with a wide-open stop an exposure of one-tenth of a second sufficed at that level between 10 and 2 o'clock on cloudless days. When this was learned from preliminary experiments, effort was concentrated successfully upon photographing three species—*Abudefduf saxatilis, Epinephelus striatus,* and *Lachnolaimus maximus.* The first is small, bright in color, and very active, but abundant in certain places. The others are large, decidedly sluggish, and occur singly, except as two or three of the last may occasionally be seen together.

By repeated random shots at schools of *Abudefduf* pictures have been obtained, which show that when the fish is viewed from the side and a lower level, at a distance of 12 to 15 feet its blue-gray markings are completely resolved into the blue-gray of the water about it. Its contour is effaced, and it is visible merely as a series of more or less disconnected parallel bars of brown and yellow. With the others the necessary procedure is different. The same individual may be found day after day in one place. Hence, by exercising patience a series of pictures portraying all the phases which either species displays may be secured by leading a single fish from one characteristic environment to another and photographing it in each. Through offering them

food this has been accomplished with *Epinephelus* and *Lachnolaimus*, and permanent records of their striking changes in coloration are available, from which it appears that, under appropriate circumstances, they may be far less conspicuous in the open than their own shadows upon the sandy bottom.

Reverting to the second of the cardinal points of the present report, we may note that there are many indications that the colors of fishes are correlated with their habits; hence the importance of being able to classify the animals with reference to their behavior requires no emphasis. As a step towards the accomplishment of this end it was proposed at first to examine a few individuals of each of many species in order to separate the diurnal from the nocturnal feeders. But the stomach contents of the snappers (*Neomænis* spp.) threw such light upon the question of the distastefulness or immunity of some of the small bright-colored fishes, that, for a time, this phase of the investigation was prosecuted at the expense of the original plan.

From an examination of stomach contents alone it is at present possible to assign only 9 species to the nocturnal group. These are *Anisotremus virginicus* and *Hæmulon macrostomum*, *parra*, *plumieri*, and *sciurus;* the three snappers, *Neomænis analis*, *apodus*, and *griseus;* and *Upeneus martinicus*.

The statement above is based upon the following facts: 170 Hæmulidæ were examined, of which 81 were taken with dynamite at about 5 a. m. and 89 at 5 p. m. Of the whole, only 3 specimens of *H. plumieri*, out of a total of 52 for that species, failed to conform to the rule that full fishes are taken in the morning and empty ones in the late afternoon. 208 snappers, of which 160 were taken about 5 a. m. and the remainder 12 hours later, showed 27 (12.98 per cent) exceptions to the same rule; but, as the average bulk of food the fishes contain is greater in the morning than in the afternoon, the figures do not accurately measure the proportionate amount of feeding done by night and day. It is also noteworthy that 14.3 per cent of the snappers' stomachs are empty in the morning, while only 8.7 per cent contain food in the late afternoon. This means, unless more extended observation should alter these proportions, that upon the average something less than 8.7 per cent of the feeding of the three species of *Neomænis* is done by day. The discrepancy between this figure and that first mentioned above may be accounted for in either or both of two ways: some fishes may feed ravenously in the forepart of the night, hunt less eagerly for food during the later hours, and digest their total catch before morning; or a small proportion may make a complete failure of their night's foraging. There is, indeed, some evidence that the latter alternative explains the difference in question, but in no case can there be doubt that the snappers are justly considered nocturnal feeders.

Only 15 specimens of *U. martinicus* were examined—4 in the morning and 11 in the afternoon—but as there were no exceptions to the rule among them, it may be assumed that they also feed by night.

It was interesting and rather unexpected to find that *Ocyurus chrysurus* and *Epinephelus morio* feed indifferently at any time throughout the 24 hours.

The food of the snappers, apart from the fishes it includes, calls for little comment at present. It suffices to say that it consists very largely of crustacea, about 20 species of which were identified in it. Approximately half of these were brachyura. Cephalopods, chiefly octopi, were found in less than 5 per cent of the fishes examined. Annelids occurred rarely, except upon special occasions, as at the time of the palolo swarm, and other food constitutes so small a fraction of the snappers' diet as to be practically negligible.

Of fishes, not less than 17 species were taken from the snappers' stomachs. Three were not identified. The others were as follows:

Abudefduf saxatilis.	H. plumieri.	Siphostoma sp.
Actæis moorei.	Iridio bivittatus.	Sparisoma flavescens.
Amia sellicauda.	Ocyurus chrysurus.	S. hoplomystax.
Atherina sp.	Scarus punctulatus.	Stolephorus sp.
Hæmulon flavolineatum.		

The above is a thoroughly representative list of the smaller fishes of the region. The different ones are encountered in numbers roughly proportionate to their abundance. Those most commonly found were *Atherina*, *H. plumieri* juv., *Iridio bivittatus*, *Scarus punctulatus*, and *Stolephorus*. It is interesting to note that the more brightly colored types are duly represented in both lists. *Iridio bivittatus* and *Ocyurus chrysurus* have patterns of strongly contrasted colors. *Scarus punctulatus* is perhaps the brightest of the smaller parrot fishes of the region. There are few fishes in the local fauna that are more gaily colored than *Abudefduf* with its bands of brown, or black, and yellow on a blue-gray ground, and the scarlet *Amia* with its two jet-black spots on either side has scarce a peer. All in all, the facts neither lend nor leave much support for the hypothesis that bright-colored fishes are distasteful or immune.

Seining operations upon the grass-flats yielded 24 species, but these are not all members of one bionomic association. Some were represented by scores of specimens and were rarely wanting in the haul, but 4 contributed only 1 individual each to the grand total. These are *Amia* sp., *Scorpæna* sp., *Teuthis hepatus* juv., and *Xyricthys* sp. With the exception of the last, all are probably strays, and it seems well to omit them from further consideration in the present connection.

The flats upon which the fish were secured are neither completely nor uniformly covered with the turtle grass. In some places its blades are short, and the tufts in which they grow are sparsely distributed. In that case the sand is relatively bare, or may be fully exposed in patches. This seems to explain the mingling of characteristic sand-dwellers with other types. Small flounders and lizard fishes (*Synodus fœtens*) were taken upon several occasions, but both bed themselves in sand habitually when resting, and may be seined on clear sandy bottom near shore. Both are gray, marked with flecks or bands of darker gray or brown. This color combination is shared with other animals living there. Hence their characteristic environment is clearly not the grass flat as such, and their presence merely marks its imperfection. *Xystæma cinereum* juv., *Sphyræna barracuda* juv., and *Actæis moorei* may be seen or taken as commonly or even more frequently in other places, and may also be excluded with reason from the grass-flat association.

There is some question whether all the remaining species should be retained in the revised list, but that point may be waived for the present; 10 of the 15 are wholly or largely of an unchangeable green color, or have definite green phases that are assumed in the midst of green surroundings. It is noteworthy that so large a proportion of them repeat, or are capable of repeating, the dominant color-note of the objects among which they live. The significance of the record is scarcely less obvious if it should be admitted that all revision of the lists is illegitimate. The most mechanical interpretation shows that 11 of the 24 species (45.8 per cent) whose range includes the grass flats are strongly marked with their distinctive color. Green occurs with no such frequency as this among fishes as a whole. Indeed,

if these species, others that may hereafter be taken with them, and such surface-swimmers as *Tylosurus*, *Hemiramphus*, and *Atherina*, whose green is a "water color," be excluded, no significant fraction of such a list may be compiled from the whole fish fauna of the region. It is, therefore, conclusively proven that among these fishes the occurrence of this color is correlated with its presence in their environment.

It has now been determined that countershading is all but universal among reef fishes. Their color changes are adaptive, and their colors correlated with their habits in such a way that their conspicuousness is thereby distinctly reduced. There is no correlation of bright colors with special modes of defense, and no evidence that bright-colored types enjoy immunity greater than that of their fellows. The hypotheses of warning and immunity coloration, or signal and recognition marks, explain no such facts as these. But it is to be noted that while this research leads one to reject those hypotheses, it is consistent with the hypothesis of evolution through natural selection.

Nerve-Conduction in Cassiopea, by Alfred Goldsborough Mayer.

Studies of the past three years have shown the importance of hydrogen-ion concentration in determining the rate of nerve-conduction in *Cassiopea*. Ordinary distilled water often remains acid, even though air freed from CO_2 by means of soda-lime has been bubbled through it for 72 hours. Accordingly, Professor George A. Hulett kindly arranged to have 144 liters of distilled water prepared in accordance with his well-known method in his laboratory at Princeton University. This water was sealed in 144 Pyrex flasks and thus transported to Tortugas. The hydrogen-ion concentration of each flask was tested separately, the range being 0.8×10^{-6} to 1.0×10^{-6} and the average being 0.9×10^{-6}, or 6.04 PH. 50 liters of this water were placed in a green-glass carboy and air freed from CO_2 was bubbled through it at an active rate for 78 hours, after which the water in the carboy had a hydrogen ion concentration of 10^{-8} which it maintained for 8 days while experiments were being conducted with it. Its alkalinity was probably due to soda derived from the glass carboy, the balance being maintained by a tendency of the water itself to become acid. Professor J. F. McClendon determined the PH of the Tortugas sea-water to be from 8.1 to 8.22, and dilution with this PH 8 distilled water maintained a practically normal and constant hydrogen-ion concentration in the solution, even when the sea-water was diluted with its own volume of distilled water.

It will be seen that the decline in rate of nerve-conduction with dilution of the sea-water is apparently the same as that of the conductivity of the sea-water when similarly diluted, the electrical conductivity of the sea-water being determined by Kohlrausch's method. It should be said, however, that the decline in concentration of the cations of sodium, calcium, and potassium also follow nearly the same law and the rate of nerve-conduction is proportional to the decline in concentration of these three cations and not to that of the sea-water cations as a whole.

Professor Ralph S. Lillie is right in his recent paper in the *American Journal of Physiology* (vol. 41, page 133) wherein he states his belief that the rate of nerve-conduction in *Cassiopea* in diluted sea-water declines in a similar ratio as the electrical conductivity of sea-water, and not in accordance with the law of adsorption, as I had supposed.

The distilled water used in my previous experiments was slightly acid and therefore stimulating in weak and depressant in stronger concentration, thus giving the semblance of an adsorption curve. The relation between

electrical conductivity and various physiological reactions has been pointed out by Pfeffer, Bernstein, Höber, and many others.

Table 7.—*Rates of nerve-conduction when Tortugas sea-water is diluted with aerated, alkaline, distilled water having a hydrogen-ion concentration of about 10^{-8}.*

Composition of solution.	Rate of nerve-conduction.	Electrical conductivity of Tortugas sea-water diluted with distilled water of P. H. 7.8 at 30° C.
Natural sea-water	100	100
95 volumes of sea-water + 5 volumes of distilled sea-water	96.23	....
90 volumes of sea-water + 10 volumes of distilled sea-water	91 44	92.16
80 volumes of sea-water + 20 volumes of distilled sea-water	79 51	81 38
70 volumes of sea-water + 30 volumes of distilled sea-water	73 91	71 53
60 volumes of sea-water + 40 volumes of distilled sea-water	65 72	64.26
50 volumes of sea-water + 50 volumes of distilled sea-water	54 16	54 08

As the rate of nerve-conduction in diluted sea-water declines in the same ratio as does the electrical conductivity, we might seem justified in assuming that it would also change in the same ratio as the conductivity when the sea-water was cooled or heated from the normal 29° C. This, however, is not the case, as is shown in table 8, the change in rate of nerve-conduction being about 2.5 times as great as that of the electrical conductivity of the sea-water.

Table 8.

Temperature of sea-water.	Rate of nerve-conduction in Cassiopea.[1]	Relative electrical conductivity of sea-water.[2]
° *C.*		
23	71 3	88.9
24	76 3	90.7
25	81.17	92.6
26	85.8	94.4
27	90.74	96.2
28	95.47	98
29	100	100
30	104.47	101.6
31	109.2	103.5
32	113.4	105.3
33	117.8	107.1

[1]Mean of Harvey, Mayer, and Cary's observations.
[2]Determined by Kohlrausch's method.

Nerve-conduction is due to a chemical reaction involving the cations of sodium, calcium, and potassium; magnesium being non essential.

The sodium and calcium cations together combine with some proteid element to form a sodium-calcium-ion proteid (see especially Osterhout, 1916). The high-temperature coefficient of ionization of this ion-proteid may account in some measure for the high-temperature coefficient of the rate of nerve-conduction, which is 2.5 as great as that of the electrical conductivity of the sea-water surrounding the nerve.

The rate of nerve-conduction is probably accelerated by an enzyme (E. N. Harvey, 1911).

R. S. Lillie, 1916, appears to be mistaken in assuming that the rate of nerve-conduction is necessarily dependent upon the electrical conductivity of the solution surrounding the nerve, for the decline in rate of nerve-conduction is practically identical whether we dilute sea-water with 0.415 molecular $MgCl_2$ or with distilled water—in other words, whether we maintain a constant electrical conductivity or reduce it nearly in the same ratio as the dilution. (Mayer, 1915, *Proc. Nat. Acad. Sciences*, vol. 1, p. 270.)

Research upon Bermuda Annelids, by A. L. Treadwell.

My work for the summer was a continuation of earlier work on a systematic study of the Leodicidæ. Since my earlier collections had covered rather thoroughly the fauna of the Tortugas, it was decided to extend the observations this year to the Bermudas. To Professor E. L. Mark, Director of the Bermuda Biological Station, and to Dr. W. J. Crozier, Resident Naturalist, I am indebted for permission to work at the station and for many courtesies shown to me while there. Miss Helen Fernald, of Columbia University, rendered very efficient service as artist.

So far as can be determined on the basis of one season's collecting, the Leodicid fauna of Bermuda differs in no considerable degree from that of the Tortugas. The main differences, as noted below, were in the relative abundance of the species, and this may have been nothing more than a seasonal variation. Verrill[1] and Webster[2] have described some species of Leodicidæ from Bermuda, and I found only 3 species which have not been already noted from this locality. One is a possible new species of *Marphysa*, another is *Leodice filamentosa* of Grube, which I have not seen at the Tortugas, and the third is a new species of *Lumbrinereis*.

Leodice longisetis Webster, mentioned by Verrill as one of the commonest species of the large Leodicidæ, was found only once—on the lower surface of a flat rock in Tucker's Bay, Harrington Sound. I have examined Webster's type of this species on the U. S. National Museum, as well as the specimen which he identified as *Leodice* (*Eunice*) *violacea*. They are certainly of the same species, the type being a very small and probably immature specimen. *Leodice* (*Eunice*) *violacea maculata* of Ehlers is also undoubtedly of this species. Verrill states that this latter is without a white nuchal band, but one in his collection labeled *violacea-maculata* has this band and is certainly *L. longisetis*. Apparently *violacea* has not been collected in Bermuda, and *violacea-maculata* is synonymous with *longisetis*.

The commonest of the large species of the coral reefs was *L. mutilata* of Webster, and it occurred also in considerable numbers in porous rocks close to the margins of the islands. Immature forms (differing from the adults in much darker coloration, but recognizable from the colorless tips of the tentacles and cirri and the prominent nuchal band) were also frequent. Apparently the breeding-season of this species is late in the summer, for a few sexually mature males were collected in July.

Leodice fucata, the "Atlantic palolo," so common in the Tortugas and in Porto Rico, has never been recorded from Bermuda, and none appeared in my collections. For this reason it was not possible to secure additional data concerning the time of swarming. *L. cariboea* Grube, a large form fairly abundant in the Tortugas, occurred only rarely.

[1]Verrill. Turbellaria, Nemertina, and Annelida of the Bermudas. Trans. Conn. Acad. Arts and Sci., Nov. 1900.

[2]Webster. Annelida from Bermuda. Bull. U. S. National Museum, 1884.

Of the smaller Leodicidæ, *L. stigmatura* of Verrill was the most abundant, occurring practically everywhere in tubes on the undersides of stones. I did not find *L. tenuicirrata* of Verrill, and am not clear as to its distinction from *stigmatura*. Some specimens of the latter species answered very closely to Verrill's description of *tenuicirrata*. *L. unifrons* was collected, but was not so abundant as *stigmatura*.

From under stones in Flatt's Inlet were collected considerable numbers of *L. articulata* of Ehlers. Verrill described *L. margaritacea* from this locality, but his species is evidently synonymous with Ehler's *articulata*. It is possible, also, that his *L. elegans* should be referred to this same species. *L. denticulata* of Webster, which, as Verrill has stated, is synonymous with *L. conglomerans* of Ehlers, was abundant on the underside of stones in membranous tubes. At the Tortugas this occurs only in sponges and grows to a much larger size than any that were seen in Bermuda. This may be a distinct subspecies from that found in the Tortugas.

What was probably *L. filamentosa* of Grube was collected in small numbers in mud at the southern end of Tuckerstown Bay, and a single specimen of *L. binominata* Verrill was found in Tucker's Bay. A few *L. culebra* Treadwell occurred in porous rock in association with *Nicidion kinbergii* Webster. As is the case in the Tortugas, this latter species is common in the porous outer layer of the rocks, a few specimens of *Lysidice bilobata* Verrill occurring with it.

Three species of *Marphysa* were collected. The most abundant species, occurring everywhere in the loosely compacted limestone rock, was *M. regalis* of Verrill. Verrill's description of this species did not include the coloration of the living animal, which is most striking, and on finding it in the Tortugas, I was misled into giving it a new specific name, *fragilis*. This is clearly synonymous with *regalis*, the latter name having priority. *Marphysa aciculorum* of Webster was abundant in muddy bays, and occurred also in porous rocks at the entrance to Flatt's Inlet. Associated with it in Ely's Harbor and at Fairyland Creek was another form, probably a distinct species. The two are quite similar, but whereas in *M. aciculorum* the gills are slender, arising from a comparatively short stem, the gills of the other species have a heavy tapering stem with a diminishing series of filaments along the side. The head has also a greenish tinge not found in *aciculorum*. Further study is necessary to establish its identity.

Stauronereis melanops of Verrill and *S. vittata* of Grube occurred very rarely. *S. rubra* of Grube, fairly abundant at the Tortugas, did not appear in my collections. *Aglaurides diphyllidia* of Schmarda was fairly common.

Specimens of *Lumbrinereis* and *Arabella* were common in all muddy and sandy places, but as surface markings are of little importance in distinguishing the species of these genera, further study is necessary before making any statement concerning them. One *Lumbrinereis*, which I shall describe as a new species under the name *L. cingulata*, was fairly common in Bermuda. Only three specimens have been found in the Tortugas, and these were dredged in 15 fathoms south of Loggerhead Key. It is unusually small, the type measuring 60 mm. in length, with 60 somites. It is nearly colorless, but has brown transverse bands on the anterior somites and brown patches on the head. The surface is thickly studded with minute tubercles, visible under rather high magnification. At Bermuda it was collected in the porous surface-rock in several localities, while the type, from Fairyland Creek, was found in a sponge.

DEPARTMENT OF MERIDIAN ASTROMETRY.*

BENJAMIN BOSS, DIRECTOR.

The general scheme of operations of this Department has been continued during the year September 1915 to September 1916, the period covered by this report. In general this scheme consists of the preparation of material for the determination of accurate systematic proper-motions and the discussion of the proper-motions already prepared.

INVESTIGATIONS.

PREFERENTIAL MOTION ACCORDING TO TYPE.

Mr. Raymond has nearly completed the investigation of preferential motion mentioned in the last report (Year Book, 1915, p. 242); and the results, together with a description of the method, will soon be published in the *Astronomical Journal.*

The following tables show the more important of the results. Table 1 gives, following the designations of the various groups of stars and their numbers, the elements A, D, and M of solar motion, and the right ascension and declination of the three principal axes of stellar motion. Table 2 gives the mean-square velocity λ_1, λ_2, λ_3, parallel to each of the three principal axes. If the velocity components in each direction are distributed according to the error-law, the velocity-figure is a generalized Schwarzschild's ellipsoid; and the mean velocity components in the three directions are given by $\bar{u} = \sqrt{2\lambda_1/\pi}$, $\bar{v} = \sqrt{2\lambda_2/\pi}$, $\bar{w} = \sqrt{2\lambda_3/\pi}$. The proper-motions, and hence $\bar{u}$, $\bar{v}$, $\bar{w}$, and M, are in seconds of arc per century, and so are affected by the mean parallaxes of the various groups. The quantities $\bar{u}/M$, $\bar{v}/M$, $\bar{w}/M$ are practically free from this effect, and are given in the last three columns of table 2.

The stars used include all in the Preliminary General Catalogue with proper-motions under 20″ per century, except some discarded for cause, such as too small weight or companions of brighter stars.

The distribution of the 493 stars of type B is so irregular that it can be handled by this method only after special treatment. This remains to be done, but the result will probably not be of great value when found. The material is included in the general group "All." "X" includes stars too faint to appear in the Draper Catalogue. These faint stars are generally supposed to belong in large part to "late" types, and the systematic motions of this group resemble those of "late" rather than "early" types. Some conclusions to be drawn from these tables follow:

(1) The motions of every group show unequal preference for three cardinal directions. The three principal axes of inertia of the velocity-figure are unequal.

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(2) The directions of the axes of least motion for the various groups cluster widely about the poles of the galaxy, the remoter ones being a little over 20° distant from it.

(3) The directions of greatest motion (vertices) show the same systematic arrangement found by Mr. Raymond by Schwarzschild's method (A. J. 676). The vertices of types A, F, and G lie well to the south of those of types K, M, and "X." ("X" did not appear in the former discussion, and G was anomalous. It here falls into line.) There seems to be no longer reason to doubt the reality of this phenomenon.

TABLE 1.

Group.	No. of stars.	Solar motion.			Pole of preference.		Intermediate pole.		Pole of avoidance.	
		A	D	M	A_1	D_1	A_2	D_2	A_3	D_3
		°	°	"	°	°	°	°	°	°
A (B8—A4)	1647	266.7	+27.9	3 88	92.4	+ 1 8	355 7	+74 7	182.9	+36 6
F (A5—F8)	656	262.9	+27.0	4.88	93.1	+ 2.1	1 0	+44 0	185.2	+45.1
G..... ..	446	256.6	+45 8	3 09	93.8	+ 3.4	356.3	+65 4	185.4	+24.4
K..	1227	272.3	+35.4	4.16	91.5	+18 0	340.5	+47 8	195 5	+36 6
M..... ..	223	272.2	+45.7	3.85	94.0	+25.3	338.6	+42.2	181.2	+40 0
X[1]..... ..	693	271.4	+42.1	2.95	83.9	+30.2	317 2	+45 8	192.6	+29 0
All< 20"..	5384	269 0	+32.5	3.68	91 9	+ 4 2	352.9	+64.7	183.8	+24 9

Pole of galaxy 190°.33,+27°.35. [1]X = (N, O, and unknown).

(4) As a by-product of the investigation we have a determination of solar motion by the method of Bravais. The solar apices for A and F types are in lower declinations and smaller right ascensions (smaller galacitic longitudes) than those of types K to X. This has been shown before by several investigators using different methods. The several values of *M* differ considerably; but this seems to be little more than the effect of different average parallaxes of the groups, except in the case of type G, where *M* seems to be actually small, perhaps because of the presence of a large proportion of stars approximating to the sun's motion (solar group).

(5) The velocity-figure for type A is very elongate and much compressed toward the galactic plane. In "later" types the dimension in the preferential direction increases comparatively little. The other two dimensions increase much more; the intermediate axis increases steadily throughout the chain of types, or nearly so. The least axis, the one perpendicular to the galaxy, increases very abruptly between A and F, but does not continue to increase. Type M shows a reversion to the shape of velocity-figure (but not to the size or orientation) shown by type A; indeed, there is a hint that the least axis passes through a maximum somewhere in the region F to K.

Two supplementary investigations are under way. One is a test of the larger groups for a possible difference between galactic and extra-galactic stars. The other is to divide the general group, and possibly the larger groups A and K, according to amount of proper-motion. It may be that the range from 0 to 20″ per century is too wide to be properly included in a single group.

TABLE 2.

Type group.	Mean square motion.			Mean motion in terms of M.		
	λ_1	λ_2	λ_3	$^{u}/M$	$\bar{v}/M$	$\bar{w}/M$
A.........	25.65	9.15	2.57	1.00	.60	.32
F......	58.05	28 78	22.66	.96	.67	.60
G......	32.26	15.81	9 96	1 74	1 22	97
K........	28 63	19 16	11.68	1 06	.88	.68
M. .	28.14	12.58	3.48	1 23	.82	.43
X.......	21 08	12.72	5.33	1.20	.93	60
All M20″...	28.91	14.99	9.89	1.16	.81	.66

SAN LUIS DECLINATIONS.

Mr. Roy has completed a preliminary discussion of the San Luis declinations. After applying all known instrumental and personal errors, mean latitudes were formed for progressively increasing declinations and for each observer in the four combinations of the two circles, clamp east and clamp west. Since the Pulkova refractions were employed in the reductions, it was to be expected that the resulting latitudes would exhibit a residual refraction term, owing to the elevation of the station at San Luis. From the residual latitudes a tangent term was computed, as in table 3.

TABLE 3.

	Latitude.					Tangent term.				
	AE.	AW.	BE.	BW.	Mean.	AE.	AW.	BE.	BW.	Mean.
	″	″	″	″	″	″	″	″	″	″
R.....	45 82	45.26	45.50	45.57	45 54	− 351	−.337	−.322	−.229	−.310
V.....	45.69	45.19	45 57	45.58	45 51	−.281	−.326	− 301	− 303	−.303
T.....	45.86	45 59	45.87	45.79	45.78	−.503	−.433	−.382	−.435	−.439
Mean..	45.79	45.35	45 65	45 65	45.61	−.378	−.365	−.335	−.322	−.350

The tangent term was then applied to the mean latitudes, producing a very fair agreement.

Certain pecularities are to be noted, however. Table 3 shows large constant differences. The differences in mean latitude among the

observers may be due to personalities in determining the nadir correction; or possibly the south-north correction should not be equally distributed each side of the zenith for all observers.

The differences in the tangent term may be largely due to personalities in bisection. As the stellar images were often very poor at great zenith distances, this explanation is entirely possible.

Another peculiarity was noted in the large deviation in the corrected value of the latitude for the extreme southern zone.

Assuming $-33° 17' 45''.47$ for the true latitude of San Luis, table 4 represents the resulting corrections to the Preliminary General Catalogue.

Table 4.—*Indicated Corrections to Preliminary General Catalogue.*

°	″	°	″	°	″
−90	0.00	−40	+0.28	+10	+0.07
−85	0.00	−35	+0.23	+15	+0.09
−80	0.00	−30	+0.18	+20	+0.11
−75	0.00	−25	+0.13	+25	+0.13
−70	0.00	−20	+0.09	+30	+0.15
−65	0.00	−15	+0.05	+35	+0.18
−60	+0.18	−10	+0.01	+40	+0.20
−55	+0.38	− 5	+0.01	+45	+0.24
−50	+0.40	0	+0.01	+50	+0.27
−45	+0.37	+ 5	+0.04		

There is an abrupt break near −60°. An examination of the fundamental curves on which the declinations of the Preliminary General Catalogue are based indicated no trace of the peculiarity noted. Since the publication of the above results, Professor Hough has called attention to a somewhat similar break in the same region when comparing the Cape Fundamental Catalogue (based on observations taken between 1905 and 1911) with the Preliminary General Catalogue.

SAN LUIS REFRACTION.

In continuation of his investigation of the San Luis declinations, Mr. Roy has analyzed the refraction results. Table 5 presents the refraction factors grouped according to observer and time of day.

Table 5.

	R.		V.		T.	
	Wt.	Factor.	Wt.	Factor.	Wt.	Factor.
Afternoon	213	1.0004	218	0.9975	197	0.9992
Early night	1916	0.9931	2108	0.9945	2279	0.9919
Late night	484	0.9908	420	0.9928	682	0.9906
Pre-dawn	90	0.9894	89	0.9907	277	0.9889
Dawn	30	0.9956	21	0.9949	58	0.9891
Early sunrise	69	0.9943	82	0.9933	48	0.9922
Late sunrise	91	1.0037	66	1.0009	27	0.9984

It is evident from table 5 that there is a distinct diurnal term. The refraction, which is well represented by the Pulkova tables in the afternoon, decreases rapidly about sunset, continues to decrease during the night, and about sunrise it begins to increase again. About an hour after sunrise the increase becomes rapid. The observations furnish no data as to the refraction at noon.

ANOMALOUS DISPERSION IN THE SUN.

The investigation described in this abstract constitutes an extension of a piece of work completed by Dr. Albrecht in the preceding year, for which the results were published in the *Astrophysical Journal* (vol. 41, p. 333, 1915). In the first article it was shown that iron lines with close companions in the solar spectrum (Rowland's Preliminary Table of Solar Spectrum Wave-Lengths) are displaced relatively to their positions in the arc spectrum; when the companion is to the violet the displacement is toward the red, and when the companion is to the red the displacement is toward the violet; in the former case the displacement is only two-thirds as great as in the latter, and in both cases it diminishes progressively with increasing separation of the two lines. These observed facts are strikingly in accord with the requirements of the anomalous-dispersion theory of Julius. Personality in the measurement of close pairs of lines was also suggested as a possible cause for the observed facts. However, it would be difficult to explain, on this ground, the observed inequality of the displacements for the two components.

In the present investigation a marked distinction was found to exist between pairs of lines in which both components are due to iron and those in which one of the components is due to some other element. For lines with companion to the red the mean deviation is $+.0115$ Å (Σ wt. 27.5) in the cases where the companion is not due to iron, and only $+.0062$ Å (Σ wt. 18) when the companion is due to iron. For companion to the violet the corresponding quantities are respectively $-.0077$ Å (Σ wt. 53) and $-.0040$ Å (Σ wt. 27). That is, for companion to the red, as well as for companion to the violet, the displacement is only one-half as great when both components of a close pair are due to iron as when one of the components is due to some other element. As above, so also in each of these subdivisions, the displacement for companion to the violet is only two-thirds as great as for companion to the red. On the anomalous-dispersion theory the observed smaller displacement for pairs of lines in which both components are due to iron is explained on the basis that the components of these pairs represent only in part physical connection in the molecule and in part entirely independent vibrations. These observed facts are also in accord with the anomalous-dispersion theory as modified by a recent suggestion of Sir Joseph Larmor.

For the lines with iron companions an attempt was made to determine a relation between displacement and difference in solar level

between the line and its companion, by utilizing the hypothesis, elaborated by St. John, "that the lines of any one element originate at depths increasing with decrease of solar intensity." The moderate preponderance of evidence in favor of a relation between displacement and ratio of intensities of the two components is not sufficient to be regarded as more than possibly a crude indication of such an effect.

The observed facts of these two investigations seem sufficiently definite to be considered established. In regard to their interpretation it may be said that the theory of anomalous dispersion in the sun as developed by Julius and modified by Larmor does account for them. However, as it is quite clear that this subject is in the early stages of development, final judgment may well be suspended for the present.

VELOCITY PLANES INDICATED BY APICES OF STELLAR MOTIONS.

The parallax problem in its application to the real motions of the fixed stars, in the investigations of Dr. von Flotow, is based upon two fundamental equations which are the keys to all further considerations. The investigation of the motions of the stars, based on the measured parallaxes and radial velocities, becomes more important with the increasing amount of data derivable from photographic methods.

A canvass of 654 large proper-motion stars of the Preliminary General Catalogue for stars with a positive measured parallax and with measured radial velocity netted 116. Computing the individual apices of these stars, and charting them, two planes of preference were clearly indicated, one along the galaxy, the other at right angles to it. The second plane very nearly passes through the generally accepted apices of preferential motion. While the available data are admittedly meager, it seemed desirable to establish a criterion whereby any particular apex might be assigned a position in or outside the two planes of velocity. For this purpose the equatorial coordinates A' and D' of the star's apex were transformed to coordinates G and H of the assumed plane, whose pole has the equatorial coordinates γ, κ. Then we have the condition

$$\operatorname{Sin} H \equiv \cos \kappa \cos D' \cos (A' - \gamma) + \sin \kappa \sin D' = 0$$

If this condition is not realized, we may attribute it to three causes:

(1) In consequence of errors in π and ρ the coordinates A', D' are in error.

(2) The assumed pole of the velocity plane may be in error.

(3) The star's apex does not belong to the assumed plane.

The first cause, assuming $d\pi$ and $d\rho$ to be observational errors, leads to the condition

$$\tan H + \Pi \, d\pi + P d\rho = 0$$

where the coefficients Π and P are known functions of the star's motion and of the position of the assumed plane. Through this

equation we are able to obtain an idea of the upper limit of $d\pi$ through the equation

$$d\pi = -\frac{\tan H}{II} - \frac{P}{II}\,d\rho$$

The second cause, designating by $d\gamma$ and $d\kappa$ the corrections to the assumed pole G_0, H_0 leads to the condition

$$E \equiv \sin H + \cos H \cos G \cos H_0\, d\gamma + \cos H \sin H\, d\kappa = 0$$

from which $d\gamma$ and $d\kappa$ are derived by the method of least squares. Again we form an upper limit for $d\pi$ from the equations

$$E + II'd\pi + P'd\rho = 0$$

or

$$d\pi = -\frac{E}{II'} - \frac{P'}{II'}\,d\rho$$

where II' and P' are known functions of the star's motion and of the corrections $d\gamma$ and $d\kappa$. The weight of each equation $E=0$ is taken as in inverse proportion to the influence of $d\rho$, *i. e.*, to the coefficient $\frac{P'}{II'}$.

Utilizing the 116 stars already mentioned, the following results were derived.

62 apices belong to the first plane (galaxy).
57 apices belong to the second plane.
The remaining 27 apices belong to neither group.
30 apices are common to both groups.

Neglecting them, the solution for the poles of the planes gives

1 plane (32 apices)	$\gamma = 192^\circ\!.2 \pm 3^\circ\!.3$	$\kappa = +36^\circ\!.2 \pm 2^\circ\!.6.$
2 plane (27 apices)	$\gamma = 151.3 \pm 4\ .6$	$\kappa = -48.0 \pm 4.5.$

The measure of precision for $d\pi$, assuming that all the stars belong to one of the two planes, is $d\pi = \pm 0''\!.055 \pm 0''\!.008\ d\rho$.

Assuming a maximum error of $d\rho = 5$ km., the condition for assigning the apices to the two planes allowed a maximum $d\pi = 0''\!.1$.

The detection of an apparent secondary plane of velocity distribution among the large proper-motion stars is interesting, and becomes more significant in view of the Director's detection of an apparently similar secondary plane of stellar distribution. The indication of such a plane was pointed out by him at the meeting of the American Astronomical Society in 1912. The pole of the plane is located at right ascension 161°, declination −35°. The plane passes within 15° of the vertex of preferential motion, and is only slightly inclined from perpendicularity to Gould's bright belt.

OBSERVATIONS.

During the year 17,422 observations were taken on 131 nights. The observations were distributed among the observers as follows: S. Albrecht, 7,333; Arthur J. Roy, 6,224; W. B. Varnum, 3,865. The circle-readings for zenith distance showed the following distribution; S. B. Grant, 4,137; H. Jenkins, 7,111; H. Raymond, 6,017. In respect to the four positions of the instrument these observations were distributed—AE 6,176, AW 6,856, BE 2,409, BW 1,981. In spite of some very bad periods in the weather, notably three consecutive weeks in June, considerable progress has been made with the fundamental program. The near completion of parts of the miscellaneous list has facilitated varying the hours of observing to cover other portions needing double transit of polar stars and 12-hour groups of clock stars. Open places have been utilized to obtain more material for determination of personal equation of the observers, particularly feet-N minus feet-S. Mr. Roy has begun accumulating material to show the effect of brightness upon the zenith distances, but the result is still inconclusive.

REDUCTIONS.

With the decrease in the number of observations, the preliminary steps in the reductions have been brought more nearly up to date. These include reduction of transits to mean wire, computation of means of microscope readings, application of corrections for division error and runs, transcription to computation sheets and there entering corrections for inclination of zenith distance wire, curvature of path, and combined telescope and circle flexure. Computation of apparent place reductions and of refractions, and the critical examination of Albany microscope readings are well advanced.

Duplicate copies of reduced transits have been checked with the original, and duplicate sets of sheets containing the fundamental stars have been drawn off. The definitive collimations, levels, and azimuth of the mire are prepared for application as far as May 1915. As has been stated in former reports, there is an effect similar to lost motion influencing the collimations; this has been eliminated by grouping the collimations over considerable periods between breaks. After the application of a temperature coefficient of $-\overset{s}{.}002$ the resulting probable error of a single determination amounts to $\pm\overset{s}{.}009$. Employing the investigations of 1905, 1908, 1909, and 1911, pivot corrections have been computed, tables laid out, and they are now being applied to the observations of the fundamental stars.

It has been possible to devote more time to the General Catalogue, particularly in collecting material from new catalogues and comparing the observations of each star with the approximate ephemeris, preliminary to the precise determination of the proper-motion.

THE ZONE CATALOGUES OF 1900.

The introduction to the Albany Zone Catalogues for 1900 has been prepared by Mr. Roy, and the catalogues are now in the hands of the printer. The publication consists of a catalogue of 8,276 stars observed by Professor Lewis Boss in the zone between 20° and 41° of south declination, a catalogue of 2,800 stars observed by Mr. Arthur J. Roy in the zone between 2° of south and 1° of north declination, a short catalogue containing the standard star positions observed in determining the system upon which the zone observations are based and a number of miscellaneous star positions, and a fourth part containing a few miscellaneous stars observed by Mr. Roy. The appendix contains a list of the proper-motions amounting to more than 10″ a century, derived from a comparison of available material with the positions given in zone 20° to 41° of south declination.

STAFF.

The Director has continued his investigations of systematic stellar motions and related problems. Dr. S. Albrecht, aside from his duties as observer, has carried on his investigations of standards of wave-length. Dr. A. von Flotow has extended his study of the real motions of those stars with observed parallaxes and radial velocities. Mr. S. B. Grant has divided his time between instrumental and computational duties. Mr. H. Jenkins has undertaken similar duties. Mr. H. Raymond has continued his investigations of stellar velocity distribution. Mr. A. J. Roy has remained in charge of the observing program and has largely supervised the reductions; his investigation of the San Luis declinations continues. Mr. W. B. Varnum, besides his duties as observer, has been engaged in the preparation for reduction of past and current work. The computing division consists of Mary E. Bingham, Grace I. Buffum, Livia C. Clark, Mabel A. Dyer, Alice M. Fuller, Florence L. Gale, Bertha W. Jones, Isabella Lange, and Frances L. MacNeill. Three piecework computers have also been employed.

MOUNT WILSON SOLAR OBSERVATORY.*

George E. Hale, Director.

INTRODUCTORY SKETCH OF THE YEAR'S WORK.

The present report records new and significant advances in several departments of the Observatory's work. The possibility, now well established, of determining a star's distance by simple spectroscopic and photometric observations, the confirmation of the existence of "giant" and "dwarf" stars, the detection of the periodic change of spectrum of certain variable stars, and the recognition of internal motions and suggestive differences of radiation in the central and outer parts of spiral nebulæ, are among the contributions which we owe to members of the staff engaged in the study of stars and nebulæ. Other departments have also produced results of interest, which will be briefly outlined in these introductory paragraphs before we deal in detail with the work of the year.

The sun, as our only neighboring star, still demands special attention on the observational program. The marked improvement in the photography of the higher solar atmosphere, made possible a year ago by the construction of a 13-foot spectroheliograph, has led to a distinct advance in our knowledge of the fields of force surrounding sun-spots. The vortex structure, detected on Mount Wilson in 1908, is now shown in exquisite detail. The chief point to determine is whether the forms recorded, which range from radial lines to closely coiled spirals, represent hydrodynamic phenomena, analogous to terrestrial tornadoes, or depict the lines of force of the powerful magnetic fields in the underlying sun-spots. While it is too early to draw final conclusions, the curious results of a parallel investigation seem strongly to indicate that the first hypothesis is the correct one.

The origin of the magnetic fields in sun-spots, attributed from the first to the rapid whirl of electrically charged particles in low-level vortices, still remains a subject of investigation. Adequate separation of the positive and negative charges, unless counteracted in some obscure way, would also give rise to strong electric fields, which should be revealed by the Stark effect. But while some valuable new phenomena of the electric separation of lines in vacuum tubes have been found here during the year (p. 239), no reliable evidence of the Stark effect in the sun has yet been detected.

The continued study of the magnetic fields in spots has nevertheless led to results of great interest. A considerable section of a new map of the sun-spot spectrum has been completed, and some unsuspected

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peculiarities of the Zeeman effect, demanding new theoretical and laboratory studies, have been revealed (p. 236). The most striking result, however, is another step toward the recognition of the true law of polarities of sun-spots in the northern and southern hemispheres of the sun.

The last annual report recorded the detection of an abrupt reversal in the magnetic polarities of spots at the sun-spot minimum. This would probably indicate, if the magnetic fields are due to vortices, that the vortices of spots occurring before and after the minimum whirl in opposite directions. As the spots of the new cycle appear in high latitudes, while those representing the end of the old cycle are close to the equator, it seemed easiest at first to assume that an effect of latitude was in evidence. But as the cycle has progressed, many spots appearing in low latitudes have been found to have the same polarity as those in the higher zones. It now remains to be seen whether a second reversal of polarity will occur at the spot maximum, and to interpret the bearing of these unexpected phenomena on the nature of spots and the cause of the sun-spot cycle (p. 237).

The excellent series of photographs of the sun's higher atmosphere, obtained since the completion of the 13-foot spectroheliograph, has rendered possible a statistical study of the direction of whirl in the hydrogen vortices. This has brought to light the fact that this direction did not reverse at the sun-spot minimum. If these apparent vortices were due to the effect of the magnetic fields in spots on the ionized hydrogen above them, their direction of whirl should have reversed simultaneously with the reversal of polarity of the magnetic fields below. But no such change occurred. Unless we may make the improbable assumption of a simultaneous reversal in the sign of the charge at high levels and the sign of the charge or the direction of whirl in the deep-seated spot vortex, the electromagnetic theory must be abandoned.

From the hydrodynamic standpoint, we may assume the effect of the spot on the higher atmosphere to be a direct downward suction, the direction of the whirl at the two levels being determined by the conditions existing in the upper and lower regions. Final conclusions, however, must await the arrival of the sun-spot maximum and the completion of a series of vortex experiments, which tend to strengthen the hydrodynamic view.

The parallel investigation on the general magnetic field of the sun has confirmed the conclusion, mentioned in the last annual report, that the magnetic axis does not exactly coincide with the axis of rotation (p. 240). Though the inclination of the magnetic axis is considerably smaller than in the case of the earth, the analogy between the solar and terrestrial fields, which also agree in polarity, is decidedly strengthened by the fact that in both cases the two axes fail to coincide.

The complex phenomena which may be involved in the relative displacements of lines in terrestrial and solar spectra, including the effects of pressure and motion of the gases in the solar atmosphere and the possible influences of anomalous dispersion and the Einstein effect, demand investigations of the most rigorous character for their solution. Instrumental errors, physiological complications encountered in the measurement of closely adjoining lines, and electrical or pressure displacements in the artificial light-sources used for comparison purposes must be run down and eliminated. Much progress has been made in this direction during the year. The errors involved in the measurement of adjacent lines have been detected (p. 240), and it has been shown clearly that the supposed mutual influence of such lines, instead of being due to anomalous dispersion in the solar atmosphere, results largely, if not wholly, from physiological causes (p. 241).

Turning now to inquiries regarding stars and nebulæ, we are able to record marked progress. Observations of stellar parallaxes and proper motions, the light changes of certain variable stars, the magnitudes of stars in Kapteyn's Selected Areas, and the radial velocities of stars have been systematically continued, and new methods have been effectively applied to the solution of outstanding questions of importance.

In the study of the structure of the universe, no data are more important than those relating to the distances of the stars. We have recently observed with satisfaction the rise of an active group of investigators of stellar parallaxes, whose cooperative researches are rapidly augmenting the limited data hitherto available. The use of the 60-inch reflector has rendered it possible for us to contribute to this undertaking, and the exceptional precision of the results will certainly warrant the continuance and extension of the investigation. But this process, in its very nature, is slow and laborious, and a supplementary method, of comparable precision, is greatly to be desired.

Such a method, mentioned in the last annual report, has now been developed and established as a fundamental contribution to practical astronomy. Based upon the discovery of a numerical relationship between the absolute magnitudes of stars and the relative intensities of certain lines in their spectra, it is thus directly dependent upon existing methods of parallax determination. But once this relationship has been established, it becomes possible, by means of a few simple measurements and calculations, to obtain a star's parallax from a photograph of its spectrum. The method is not as yet applicable to the earlier types of stellar spectra, and its availability is necessarily limited to the range of absolute magnitudes occurring among stars of directly measured parallaxes. Distance does not enter as a limitation, however, except as it determines the apparent magnitude which can be observed spectroscopically with the equipment available. But its simplicity and rapidity of execution will soon increase materially our

knowledge of the distribution of stars in space (p. 252). Another method, based upon the relative intensities of different parts of the continuous spectrum, should also prove to be of practical importance (p. 253). It may be applied spectroscopically, or with the aid of direct photographs taken through color screens. A new method of determining star-colors which has been developed during the year should be of special value in this connection (p. 248).

The spectroscopic method of determining parallaxes has afforded a valuable confirmation of the conclusions of Russell and Hertzsprung regarding the existence of giant and dwarf stars (p. 253). The further development of this investigation will be of importance in its bearing on the problem of stellar evolution. Here, too, the quantitative method of classifying stellar spectra, which is based upon the ratios of the intensities of certain lines, will prove of value (p. 251).

The true significance of the change of color with brightness, long recognized as characteristic of variable stars of the Cepheid class, has now been detected. All stars of this class hitherto investigated are found to go through periodic variations in spectral type, passing by gradual changes of line intensity from one type to another. The chief value of this discovery will not be confined to its bearing on the nature of these variable stars, but is likely to lie in its application to the interpretation of the spectral changes which accompany stellar evolution (p. 253).

Star clusters offer exceptional opportunities for certain researches, especially those which require the comparative study of stars at the same distance from the earth. A comprehensive study of the magnitudes and colors of stars in globular and open clusters has already yielded some interesting results. These include proof of the existence of giant red stars in globular clusters and evidence that light is not appreciably scattered in its passage through space (p. 249).

A general investigation of nebulæ, which we have long planned to undertake, will be fully organized as soon as the 100-inch telescope is completed. In spite of the many demands on the 60-inch reflector, it has been possible during the year to give more attention than formerly to work of this character.

Direct photographs of interesting nebulæ are taken regularly at the principal focus of the 60-inch reflector and occasionally on the larger scale afforded by the Cassegrain combination (p. 244). In spite of the evidence of internal motions suggested by the appearance of spiral nebulæ, no change in their form has been detected until this year. Differential measures of many condensations in the spiral M 101, made with the stereocomparator on two photographs separated by an interval of five years, yielded distinct evidence of rotation. As this has been confirmed by two measurers, using Mount Wilson and Lick photographs, its reality appears to be established. A series of photo-

graphs of promising nebulæ, made with special reference to the rigorous requirements of such work, will be taken with the 60-inch and 100-inch reflectors (p. 244).

The spiral nebula N. G. C. 4594, which we see from a point lying nearly in its own plane, affords an excellent opportunity to study the rotational motion by spectroscopic observations. The high tangential velocity of 335 km. per second for a point 120″ from the center, and the fact that the velocity is directly proportional to this distance, are both of peculiar interest. If we may assume that the dimensions and velocities are of the same order of magnitude in this nebula and in M 101, we can at once determine the order of the parallax of N. G. C. 4594. The resulting value of 0″.0002 indicates the probable remoteness of this spiral (p. 254).

The great number of the spiral nebulæ, and their striking regularity of form, render them of exceptional interest in the evolutional problem. Any evidence obtainable as to their mode of formation or their degree of condensation at various distances from the center will be eagerly sought. Thus the marked differences in color, revealed by a comparison of photographs taken with and without color screens, will repay much study (p. 248). The denser nuclear region, giving a spectrum similar to that of a star, sometimes as far advanced as the sun, is relatively yellow, while the spiral arms and the condensations along them are intensely blue. It remains to be seen whether this difference is due to the gaseous character of the outer parts, but a spectrographic observation of a bright knot 10″ from the nucleus of the spiral nebula M 33 shows the gaseous nebular spectrum, and thus supports this view (p. 255).

The color screen, in its various forms, finds many applications in astronomy. Thus Jupiter and Saturn show new belts and markings when photographed by ultra-violet light. The extension of this method to other planets is likely to prove advantageous (p. 243).

The interpretation of astrophysical observations depends largely upon laboratory experiments, which have gone forward effectively during the year. The electric furnace continues to serve as an efficient means of varying and controlling physical and chemical conditions. With its aid the study of the changes of metallic spectra with temperature has gone forward, band spectra have been produced and photographed, and various special experiments have been made (p. 257). These include an examination of the characteristics of the red lithium line, which appears to be present in sun-spots but absent from the general solar spectrum (p. 259), and some work on anomalous dispersion, undertaken to see whether neighboring lines can actually be displaced by mutual influence. The negative results obtained are in harmony with the indications of solar observations (p. 241) as well as theory. Metallic spectra, produced within vacuum tubes by bom-

barding a vapor with a stream of cathode particles, promise to be of interest when studied quantitatively (p. 260).

The measurement of secondary standards of wave-length by interference methods, in terms of the red cadmium line, has advanced rapidly since the installation of the auxiliary concave grating and the perfected quartz-invar etalons. The use of several forms of arc, in air and in vacuo, the elimination of displacements due to "pole-effects" and pressure, and the application of powerful grating spectrographs to check the interference results, should yield international secondary standards of the highest attainable accuracy (p. 260).

The further study in the laboratory of the Zeeman effect has provided a large collection of new data for the spectra of iron, chromium, vanadium, and titanium (p. 260). Corresponding studies of the Stark effect have yielded new results for lithium and calcium (p. 239). Both investigations are being extended to other elements.

On the instrumental side, the work of the year has been devoted largely to the completion of the ruling machine and the extensive labor of finishing, transporting, and erecting the 100-inch telescope. The successful outcome of the long task of figuring the 100-inch mirror, the production of an excellent grating, and the accomplishment of the work of transporting most of the heavy and cumbersome parts of the telescope up Mount Wilson, where they are now being erected, mark the beginning of the last stage in the provision of the equipment originally planned for the Observatory. The excellent figure of the large mirror is a source of special satisfaction, which we trust may be augmented in the near future through the actual use of the 100-inch telescope (p. 264).[1]

STAFF.

During the first half of the year the Director continued his solar researches in collaboration with several members of the staff. In April he was called upon by the National Academy of Sciences to assist in the organization of a National Research Council. This task, undertaken at the request of President Wilson, has occupied most of his time since that date. Dr. Walter S. Adams, Assistant Director, has continued to direct the investigations in stellar spectroscopy and has had general charge of the Observatory during the Director's absence. Professor Frederick H. Seares, superintendent of the Computing Division and editor of the Observatory publications, has carried on his researches in stellar photometry, the determination of the position of the sun's magnetic axis, and other subjects. Dr. Arthur S. King, superintendent of the Physical Laboratory, has devoted most of his time to work with the electric furnace. Dr.

[1] Owing to delays in European mails, the report of Professor Kapteyn, given on page 255, could not be referred to in this introductory sketch.

Charles E. St. John has given special attention to the supposed mutual influence of closely adjacent solar lines, and the question of possible anomalous dispersion in the sun. Professor G. W. Ritchey has completed the 100-inch mirror and made some photographs of nebulæ with the 60-inch reflector. Dr. J. A. Anderson, who joined the Observatory staff in July, is engaged in a study of the Stark effect and is collaborating with Mr. Jacomini in the ruling of gratings. Mr. Harold D. Babcock has continued his researches on the Zeeman effect and the determination of standards of wave-length by interference methods. Mr. Ferdinand Ellerman has served as Observatory photographer and carried on his work with the Snow and tower telescopes. Mr. Francis G. Pease, in charge of instrument design, has given much time to the 100-inch telescope and has continued photographic and spectroscopic studies of nebulæ. Dr. Harlow Shapley has pursued his studies of stellar photometry, star clusters, and variable stars, and devoted special attention to the spectroscopic phenomena of the Cepheids. Dr. Adriaan van Maanen has carried forward his determinations of stellar parallaxes and proper motions and the measurement of spectra to fix the position of the sun's magnetic axis; he has also studied the internal motions in spiral nebulæ. Dr. Walter Colby returned to the University of Michigan in September, after spending a year at the Observatory. Mr. George P. Luckey, after completing his observational and experimental work, resigned his position on November 1. Dr. Seth B. Nicholson, who joined the Observatory staff September 1, has devoted most of his time to solar work. Professor Alfred Joy, who joined the staff October 1, has also been engaged in the solar work. Mr. George S. Monk, who resigned his position on October 1, has assisted in the stellar spectroscopic investigations.

Professor J. C. Kapteyn, Research Associate of the Carnegie Institution of Washington, has continued in Holland his studies of Mount Wilson observations. Professor R. W. Wood, of Johns Hopkins University, spent a few days on Mount Wilson in October, photographing the Moon, Jupiter, and Saturn through color screens.

Miss Janet Howell, who held the Sarah Berliner Fellowship for 1915–1916, spent the academic year at the Pasadena Laboratory studying the Stark effect for lithium and calcium. Miss Edna Carter, of Vassar College, has recently been at work in the Pasadena Laboratory on spectra produced in vacuum tubes by the cathode discharge. Dr. Gustaf Strömberg, of Stockholm University, joined the staff in June as a volunteer assistant in stellar spectroscopy.

Dr. Charles G. Abbot, Director of the Smithsonian Astrophysical Observatory, has continued his solar investigations on Mount Wilson during the summer of 1916 with the assistance of Mr. L. B. Aldrich.

INVESTIGATIONS IN PROGRESS.

SOLAR RESEARCH.

INSTRUMENTS.

The exceptional qualities of the photographs of flocculi obtained with the 13-foot spectroheliograph, built for the 60-foot tower telescope a year ago, have thrown heavy demands upon these instruments, which are used daily throughout the period of best seeing. In order to take full advantage of the good definition afforded by the 60-foot tower, and to set free the Snow telescope for other work, the 5-foot spectroheliograph was mounted horizontally in the house at the base of the tower in December, together with a 45° plane mirror for projecting the solar image upon the vertical slit of the spectroheliograph. This mirror can be moved to one side, permitting the solar image to be used with the 13-foot spectroheliograph or the 30-foot spectrograph, which hang side by side in the concrete chamber beneath the tower.

The Snow telescope has two advantages over the tower telescope: its perfect achromatism (due to the exclusive use of mirrors in its optical train), and its comparatively large angular aperture, which is twice as great as that of the 60-foot tower telescope. On the other hand, the distortion of the large and relatively thin mirrors, when exposed to sunlight, limits seriously the period of good definition, and frequently produces a very appreciable change in the focus of the solar image during a single exposure with the spectroheliograph. This telescope is, therefore, best adapted for investigations in which large angular aperture and perfect achromatism are more urgently needed than perfection of focus and good definition.

We have therefore decided to equip the Snow telescope with a vertical spectrograph, mounted in an underground chamber of concrete, of the type which has proved so satisfactory in our previous work with the two towers. The combination will be available for Mr. St. John's investigations on the relative positions of arc and solar lines, which have been handicapped by the small angular aperture of the tower telescopes. It is extremely important to have the diameter of the light cone at the grating level much larger than the aperture of the grating itself, in order to assure perfect uniformity of illumination. This new apparatus will soon be ready for use.

SOLAR PHOTOGRAPHY.

During the year ending August 31, 1916, 84 direct photographs of the Sun were taken with the Snow telescope prior to the removal of the 5-foot spectroheliograph, together with 222 spectroheliograms, including 130 Hα and 46 K_2 images of the entire disk, and 46 K_2 prominence plates.

The following photographs have been taken with the 60-foot tower telescope by Messrs. Ellerman, Nicholson, Joy, and Campbell, who also made those taken with the Snow telescope: photoheliograms, 207; 5-foot spectroheliograms (Hα, of entire disk), 139; 13-foot spectroheliograms, 1,609.

IDENTITY OF THE DARK "FILAMENTS" WITH PROMINENCES.

The hydrogen flocculi of the higher solar atmosphere, including the long dark objects which M. Deslandres has called "filaments," were first photographed with the Rumford spectroheliograph of the Yerkes Observatory in 1903. Their essential identity with prominences was at once suspected, and was confirmed by observations near and at the limb made at that time and in subsequent years. A good case in point is illustrated in our paper on "Solar Vortices" in the *Astrophysical Journal* for September 1908.

The same conclusion has been reached by Evershed, Riccò, and others who have investigated these objects, but it has been disputed by Deslandres, who maintains that the identity has not been proved. Without going into details, which will be given in full elsewhere, it may be said that a great number of prominences photographed with the 13-foot spectroheliograph fully bear out our original interpretation. Many beautiful examples of prominences photographed with the center of Hα, while half projected against the disk and half rising above the limb, occur in our collection of plates.

STEREOGRAMS OF CALCIUM AND HYDROGEN FLOCCULI.

The rapid changes in form characteristic of most phenomena of the solar atmosphere interfere seriously with the preparation of reliable stereograms. Several years ago we published stereograms of the calcium flocculi, made with an interval of several hours, which show the sphericity of the solar image and the relief of the H_2 flocculi. But these were small scale images of a region in the solar atmosphere where the changes in form are much less rapid than at the higher hydrogen level.

To overcome the difficulty, it is necessary to limit the interval between the photographs to the shortest possible time. Under the conditions used in our work, an application of the criterion of Helmholtz indicates that the angle through which the sun rotates in 5 minutes should be sufficient to show true stereoscopic relief. Combining properly a pair of photographs taken with this interval, we see the dark hydrogen flocculi, and especially the long dark filaments which have been identified with prominences, rising plainly above the surface.

We must be on our guard, however, against false effects of relief due to various causes. The true stereoscopic relief with such a time interval is very small, and may sometimes be completely masked by false effects. To check its reality, we have photographed a globe bearing small objects in relief, and have found that by turning it through

the same angle as that used in the solar work, we can obtain pairs of photographs which unite into true stereograms. It may be added that we have confined ourselves to Helmholtz's limiting angle and have not adopted the much smaller value given by Pulfrich. When used with care, and with sufficient precaution against possible errors, these stereograms may be useful in studying the relative levels of the flocculi. It may be added that they give results in harmony with conclusions obtained by other means.

A NEW MAP OF THE SUN-SPOT SPECTRUM.

In 1907 we prepared and distributed to observers a map of the sun-spot spectrum on a scale of 2 mm. to the angstrom. Some very fine photographs of the spectrum of a large spot, recently made by Mr. Ellerman in the second order of the 75-foot spectrograph, have rendered possible the preparation of a map on a scale of 1 cm. to the angstrom, which is sufficient to show the chief phenomena of the Zeeman effect, including some interesting anomalies.[1] The polarization phenomena are brought out to special advantage through the use of a compound quarter-wave plate, mounted in conjunction with a Nicol prism just above the slit of the spectrograph. At present the map covers only the region from $\lambda 6000$ to $\lambda 6450$, but it will be extended over a greater range as soon as sufficiently perfect photographs of other regions can be obtained.

The definitive reduction of photographs of sun-spot spectra, which involves the measurement of the components of triplets and quadruplets, is seriously complicated by the physiological errors which enter when one attempts to bisect closely adjacent lines. As the discussion of the results demands an elimination of such errors, the final studies have been further delayed until they can be evaluated with the Koch machine or otherwise. Meanwhile the studies of Mr. St. John (p. 240) have shown how seriously such errors may vitiate conclusions which ignore their existence.

THE ZEEMAN EFFECT IN SPOTS NEAR THE SUN'S LIMB.

When a spot is observed close to the sun's limb, the lines of force of its magnetic field vary greatly in inclination at points but slightly separated from one another. At the center of the spot, where they are apparently radial, they lie nearly at right angles to the line of sight. In this case the polarization phenomena should be those observed in the laboratory across the field of a magnet, *i. e.*, the three components of a triplet should be plane-polarized, permitting the outer components or the central one to be cut out at will with a Nicol prism. On the inner edge of the penumbra the lines of force are directed toward the

[1]Behavior of the *p*-components of triplets as though their edges were circularly polarized in opposite directions; presence of triplets which indicate stronger fields in the penumbra than in the umbra; transmission of both *n*-components of triplets at the center of spots where the compound quarter-wave plate and Nicol completely cut off one component in the penumbra, etc.

observer, while at its outer edge they extend in the opposite direction. Thus with a Nicol and quarter-wave plate the red component should be cut off in one case, the violet component in the other.

All of these effects are easily seen with the 75-foot spectrograph, used in conjunction with the large solar image of the 150-foot tower telescope. When very near the limb, the lines of force directed toward the observer from the inner edge of the penumbra are absent, presumably because of the depression of the umbra and penumbra below the level of the photosphere. Thus a polarity test for a spot in this position would be misleading, as the elliptical polarization would be due to the oppositely directed lines of force on the outer edge of the penumbra.

SUN-SPOT POLARITIES.

The remarkable fact that spots which appear before and after the sun-spot minimum are opposite in magnetic polarity was mentioned in the last annual report. At that time the spots of the new cycle were still occurring in high latitudes, but many have since appeared near the equator. With no more than 1 or 2 per cent of exceptions, spots of the new cycle, irrespective of latitude, are opposite in sign to

Spot cycle and hemisphere.	Direction Hα whirl.			Polarity of preceding spot.		
	Right-handed.	Left-handed.	Undetermined.	V	R.	Undetermined.
Preceding cycle:						
Northern Hemisphere	0	4	3	7	0	0
Southern Hemisphere	10	4	8	2	17	3
Present cycle:						
Northern Hemisphere	9	34	58	2	83	16
Southern Hemisphere	33	2	56	79	0	12

those of the old cycle. Thus the assumption that the polarity depends upon the latitude breaks down; it appears to change with the cycle, in spite of the difficulty in assuming that successive cycles differ so markedly. It is barely possible, however, that another general reversal of polarities will occur at the spot maximum, to which we are looking forward with interest.

The excellent Hα plates taken with the 13-foot spectroheliograph have enabled Mr. Nicholson and the Director to make a statistical study of a long series of hydrogen flocculi. The direction of the whirl is given in the accompanying table, which also shows the polarities before and after the minimum.

The tabular values are numbers of spots for which the polarities and the structure of the Hα flocculi have been examined. V and R in the table heading indicate the transmission of the violet and red

components, respectively, by the Nicol and compound quarter-wave plate. The large percentage of undetermined cases for the Hα whirl arises from the fact that small spots oftentimes show no vortex structure, although the polarity is easily determined.

It thus appears that while the magnetic polarities of the spot-fields reversed at the minimum, the direction of whirl in the overlying hydrogen vortices did not reverse. This seems to be a fatal objection to the hypothesis that the configuration of the hydrogen vortices is caused by the magnetic field of the spot, which might impel moving ions to arrange themselves along the lines of force. The vortex experiments undertaken last year also oppose the electromagnetic explanation, and point to the hydrodynamic hypothesis. But this must take into account the fact that the direction of whirl in the low-lying spot-vortex apparently reversed without changing the sign of the secondary vortex above. This would be quite possible if the effect of the spot on the overlying atmosphere were confined to a vertical suction, leaving the sign of the secondary vortex thus induced to be determined by the conditions existing at its higher level. As the rotation law at this level is essentially the same before and after the minimum, the sign of the whirl should remain constant.

The cause of the reversal of spot polarities at the minimum still remains a mystery, and the possibility that the sign of the charge, rather than the direction of rotation in the vortex, is reversed must not be wholly ignored. We have no evidence pointing to such a conclusion; indeed, we have as yet no direct evidence of the existence of an electric charge in the spot-vortex.

THE STARK EFFECT.

As stated in previous reports, the character of the lines in sun-spot spectra offers no apparent reason to hope for the detection of such phenomena as the presence of an electric field might induce. The hydrogen lines, which are enormously widened and split into many components by the electric field within a vacuum tube, are not widened, but actually narrowed, in sun-spot spectra. It is true that they represent a comparatively high level, and that lines originating at greater depths should better serve our purpose. But for most of these the Stark effect, if any exists, is unknown. The spot triplets certainly offer nothing of promise. With a Nicol and quarter-wave plate we can cut off completely their ellipitically polarized n-components, leaving a sharply defined p-component which is narrower than the corresponding line in the solar spectrum beyond the limits of the spot. Since no circular or elliptical polarization has yet been found for the components of a line split up by an electric field, the narrow p-component must presumably contain any evidence that exists for the Stark effect; and yet we find it narrowed rather than widened.

The Stark effect is nevertheless of such fundamental importance that it has seemed advisable to study it carefully in our laboratory. We owe to Professor Stark's kindness a beautifully made hydrogen tube of the form he has used so successfully. In the absence of a skilled glass-blower, however, it has been necessary usually to employ the simple form of tube used by Lo Surdo. Miss Howell, after successfully overcoming the difficulties encountered in the course of this work, has obtained some interesting new results for lines of lithium and calcium. For the lithium lines $\lambda 4602$ and $\lambda 4132$ she finds in the transverse effect the same general character of separation as that described by Stark, though her measurements give, on the whole, larger displacements than he found. In the longitudinal effect, however, Miss Howell's photographs show two sets of *unpolarized* components which correspond in number, and roughly in intensity, with those observed in the transverse effect, but which have distinctly smaller displacements. In addition, the strong central component of $\lambda 4132$, moderately shifted toward the violet, is found unpolarized in both the longitudinal and transverse effects. Displacements toward the violet are greater than those of opposite sign, reaching a maximum of 3.1 Å for 20,000 volts per centimeter in the case of the transverse effect for $\lambda 4132$.

The H and K lines of calcium are each resolved by an electric field into two components for the transverse effect and three for the longitudinal. In the latter case all these components are unpolarized and are sharp and clear. For the transverse effect, however, the components are broad and hazy, the stronger one, on the red side, being unpolarized in each case, while the weaker one is polarized. The maximum displacement occurs in the case of the K line, amounting to about 1.4 Å toward the red for 20,000 volts per centimeter in the longitudinal effect. This is comparable to the separations observed in the case of hydrogen, helium, and lithium.

The lithium line here in question does not exist in the sun, and it remains to be considered whether the wings of the H and K lines in spot spectra are due to an electric field. When we remark the great strength and breadth of these wings outside of spots, and remember how easily similar wings are produced in the laboratory without the aid of an electric field, it can not be said that such indications are yet entitled to any weight. Steps are now being taken to produce more brilliant spectra, since high dispersion must be employed to determine whether lines of iron and other similar elements are appreciably affected by an electric field.

GENERAL MAGNETIC FIELD OF THE SUN.

The chief work of the year has been a continuation of the attempt to determine the inclination of the sun's magnetic axis and the period of its revolution about the sun's axis of rotation. The three lines $\lambda 5247.737$, $\lambda 5300.929$, and $\lambda 5329.329$ have been measured by Mr.

van Maanen in 625 spectra, representing observations on 20 days. Altogether 46 days, distributed over the interval of 110 days for which plates are available, have been finished. From observations on 37 days, covering an interval of about two and one-half months, the following preliminary results have been derived by Mr. Seares:

Period $= 31^d51 \pm 0^d62$
Inclination $= 5°2 \pm 0°5$
Magnetic pole on central meridian, 1914, June 25.07 ± 0^d43.

INVESTIGATIONS ON THE RELATIVE POSITIONS OF SOLAR AND TERRESTRIAL LINES.

Mr. St. John has continued his extensive researches on the relative positions of solar and terrestrial lines, in order to determine their bearing upon pressure, motions, and the possible influence of anomalous dispersion and the Einstein effect in the solar atmosphere. Independent sets of observations are being made with several different spectrographs, and a further check will be afforded by the use of interference methods. Mr. St. John is also continuing his work on the Evershed effect in sun-spots and carrying on an investigation of the solar rotation in order to detect any possible change in its period.

ERRORS IN THE MEASUREMENT OF CLOSELY GROUPED LINES.

The data relative to differences between solar and arc lines have been greatly increased during the year by Mr. St. John, but the major effort has been an investigation of the accuracy of measurement and of the possible mutual influence of closely adjacent solar lines. Personal equation and its elimination have been given much attention. The most important result is the evidence of systematic errors for close pairs of lines in the Rowland tables. The measurement of solar lines near the limit of spectrographic resolution is a matter of extreme difficulty and liable to systematic error. Separations have been determined, as far as possible, upon each of five series of spectrograms with dispersions varying from 0.23 to 1.8 Å per millimeter. For incomplete separation, those obtained from registering microphotometer curves are smaller than those found by filar-micrometer settings. Near the limit of resolution, microphotometer curves, settings on the edges of the doublet and of lines similar to its components, and micrometer measurements have been employed. The first appears more reliable and yields smaller values than the third. Separations equal to the theoretical spectrographic resolution, though serving to detect duplicity, are not sufficient for micrometer measurements to the third decimal place of angstrom units.

Filar-micrometer measurements of the separation of close doublets vary with the width of the slit, the precision of the focal settings, and the density and definition of the spectrograms, those of the finest definition yielding the lowest values for doublets near the limit of resolution. Whatever decreases the intensity of the common region relatively to that of the continuous spectrum produces a tendency on

the part of the measurer toward increased separation. This seems to be an effect of contrast, the maximum being located nearer the free edge of the line, for which the contrast is greater.

For close pairs to the red of λ4000, component intensities 3 and 4, with mean separations of 0.276, 0.145, and 0.75 Å, the Rowland separations exceed the Mount Wilson values systematically by +0.003, +0.008, and +0.013 Å, respectively. That these differences are errors in the Rowland values is made probable by the agreement between the results of the diverse methods used at Mount Wilson, the concordance between the spectrograms of different orders, and the established tendency toward over-separation with any departure from best conditions.

A FURTHER TEST OF THE ANOMALOUS DISPERSION THEORY.

A mutual influence of closely adjacent Fraunhofer lines which displaces them in opposite directions, a quasi-repulsion, is a deduction from the anomalous dispersion theory. An observational confirmation of such an influence would be a direct proof of the efficiency of anomalous dispersion in producing solar phenomena; its value as a criterion is evident. For solar lines with companions to the violet the sun-arc displacements should be greater than the mean for lines of the same pressure group, and less for solar lines with companions to the red; further, the separation of the adjacent lines should be greater in the solar spectrum than in arc spectra.

Pressure group.	Sun-arc displacements in angstroms and number of lines		
	Mean for group.	Lines with companions to red.	Lines with companions to violet.
*a, b, c*4 . . .	+0 0039 (213)	+0 0042 (30)	+0 0040 (59)
*c*5, *d* . . .	−0.0063 (125)	−0 0062 (25)	−0 0052 (21)
e . .	+0.0142 (34)	+0 0156 (5)	+0 0110 (6)

Mr. St. John has tested these points, with the results for the sun-arc displacements shown in the accompanying table, while for 45 pairs the mean separation in the solar spectrum, within the limits of error, is identical with that in arc spectra. In neither case, therefore, do the results support the anomalous dispersion theory. The behavior of lines with companions is like that of similar free-standing lines. Whether the separation in the solar spectrum is greater or less than in arc spectra depends upon the configuration of the pair. For 8 of the 45 pairs it should be larger and for 15 smaller than in arc spectra. Actually the differences are 0.005 and 0.0035 Å, respectively, in the required directions.

Comparison between the Rowland and International wave-lengths of the iron lines shows apparent displacements of the sign required by the hypothesis of mutual influence (Albrecht). As the previous

investigation had revealed errors in the Rowland wave-lengths comparable in sign and magnitude to the deviations observed by Albrecht, the 104 lines used by him were investigated. The correspondence between the Albrecht deviations and the results of this investigation affords so close a parallel as to leave no doubt that the deviations are to be attributed to systematic errors in Rowland's tables. They furnish no valid evidence, therefore, that the relative positions of the Fraunhofer lines are systematically displaced by mutual influence, while, as just shown, the sun-arc displacements (372 lines) and the relative separations of the components of 45 close pairs in solar and arc spectra indicate that, within the limits of error, mutual influence is absent from the solar spectrum. In so far as mutual influence is a necessary corollary of anomalous dispersion, evidence for the latter is therefore also absent.

INVESTIGATIONS OF PLANETS, STARS, AND NEBULÆ.

OBSERVING CONDITIONS.

The observing conditions at night for the year ending August 31, 1916, were more favorable than for several years past. This was in spite of the fact that January was one of the stormiest months on record and furnished the lowest percentage of observing weather (14 per cent) since the establishment of the Observatory. The months of April, May, and June were exceptionally favorable for observational work, summer conditions beginning much earlier than usual. The 60-inch reflector was in use 210 entire nights and during a part of 78 nights. No observations were made on 78 nights. Out of 3,591 hours of darkness the instrument was in use 2,306 hours, or 64 per cent. The mirror was resilvered twice during the year, in February and June. The statistics for each month are given below:

Date.	Hours of darkness.	Hours clear	Hours cloudy	Hours lost silvering and repairing	Hours of exposure time	No. of photographs.	Observations.		
							All night.	Part of night.	None.
1915									
September	295	207	88	0	164	164	19	5	6
October	336	273	63	0	177	268	24	5	2
November	330	159	171	0	113	146	8	13	9
December	346	162	184	0	121	85	10	11	10
1916									
January	346	47	299	0	24	37	1	8	22
February	308	155	153	20	110	108	11	6	12
March	324	199	125	3	131	197	15	8	8
April	286	220	66	1	161	214	22	6	2
May	266	223	43	0	162	147	23	6	2
June	230	219	11	24	142	178	24	2	4
July	255	241	14	0	151	296	29	2	0
August	269	236	33	0	179	180	24	6	1
Totals	3591	2341	1250	48	1638	2020	210	78	78

The conditions of seeing on a scale of 1 to 5 and the wind records are given in the following table:

Seeing.		Wind.	
<1 to 1	47 nights	Very high	6 nights.
1 to 2	82	High	17
2 to 3	134	Brisk	43
3 to 4+	30	Moderate	39
		Light	132
		Calm	99

During the year the U. S. Weather Bureau installed at the Observatory a Marvin automatic recording rain-gage, maximum and minimum thermometers, and a Richard thermograph. In addition to sending written monthly records of meteorological data, Mr. Hoge, night assistant with the 60-inch reflector, furnishes each morning to the Los Angeles office of the Weather Bureau, telephonic reports of the current weather conditions which are being included in the daily weather charts published by the Bureau.

The total precipitation at Mount Wilson during the year ending August 31, 1916, was 36.75 inches, of which the snowfall amounted to 49 inches. The highest temperature was 93° F. on July 11, while the lowest was 14° F. on January 30.

MONOCHROMATIC PHOTOGRAPHY OF JUPITER AND SATURN.

The important results obtained by Professor Wood through monochromatic photography of the moon with ray-filters transmitting limited regions of the spectrum made an extension of this investigation to the planets of exceptional interest. Accordingly the 60-inch reflector was placed at his disposal for four nights in October of last year, and a complete series of photographs of Jupiter, Saturn, and the Moon was secured by him at that time.

The photographs were made at the 80-foot focus of the reflector, the regular double-slide plate-carrier being employed for the purpose. Four ray-filters were used. The filter for ultra-violet light consisted of a bromine cell 5 mm. in thickness, with uviol glass windows, which was placed directly in front of the photographic plate. In case a very restricted region of the spectrum was desired this filter could be supplemented by a cell containing a very dilute solution of potassium chromate. The two filters in combination transmit the spectral region from $\lambda 2900$ to $\lambda 3250$. The remaining filters consisted of stained gelatine films mounted between thin sheets of plate glass, and transmitted respectively $\lambda 4000 - \lambda 4500$, the region above $\lambda 5000$, and the region above $\lambda 7000$.

The photographs of Jupiter show numerous differences in light of the different colors. On the infra-red images there is less darkening of the disk toward the planet's limb and the cloud belts are very inconspicuous. Moreover, the upper dark polar cap shades off gradually, while on the violet and ultra-violet photographs the boundary is sharply defined. The latter also show a doubling of the bright belt above the equatorial zone which is not seen on the other negatives.

The photographs of Saturn are of special interest. The infra-red image shows the ball of the planet nearly devoid of markings, with only traces of the belts visible. These are distinct on the yellow image, which presents the usual visual appearance of the planet. On the violet photograph, however, a very broad dark belt surrounds the planet's equator, covering the region which is brightest in yellow light, and in addition a dark polar cap of considerable size makes its appearance. These dark regions appear also on the ultra-violet image with slight modifications. They may be due either to the presence of a ring of dust forming an extension of the crape ring down to the ball of the planet or to the existence in the planet's atmosphere of some material or gas capable of absorbing violet and ultra-violet light. The latter is perhaps the more probable.

Photometric measures of the density of the plates between the ball and the ring, made by Mr. Babcock, indicate a greater density for the ultra-violet than for the yellow image.

DIRECT PHOTOGRAPHY.

The following photographs of spiral nebulæ were made during the year by Mr. Ritchey at the Newtonian focus of the 60-inch reflector:

N. G. C. 224	Exposure 9^h 10^m	N. G. C. 4736	Exposure 2^h 0^m
2403	8 0	5857 } 5859 }	6 7
2683	5 0		
3627	1 0	6946	10 0

Mr. Pease has obtained the following negatives at the same focus of the reflector:

N. G. C. 2371-2	Gaseous nebula.
2392	Planetary nebula.
4594	Spiral nebula almost edge-on.
5544-5	Two overlapping nebulæ, one edge-on, the other in plan.
6070	Spiral nebula in plan.
6309	Gaseous nebula.
6555	Spiral in plan in Milky Way.
6703	Gaseous nebular spot.

A plate of Nova Lacertæ, on which the North Polar Sequence was superimposed, gave for the Nova a photographic magnitude of about 13.5.

MEASUREMENT OF PARALLAXES AND PROPER MOTIONS.

During the past year 387 direct photographs, including 518 exposures, have been taken at the 80-foot focus of the 60-inch reflector. Of these, 404 exposures were for the determination of parallaxes, 93 for the determination of proper motions of large proper-motion stars, and 21 for miscellaneous purposes.

For 17 parallax fields, each with 12 to 20 exposures, the measures and reductions have been finished, making a total of 34 finished fields. All stars with a very few exceptions were selected from Boss's "Preliminary Catalogue" and are of spectral types F to N, with magnitudes less than 5.5, and proper motions less than 0".5. The mean probable error of a final parallax is ±0".006. From the first 20 fields evidence was derived that systematic errors due to a magnitude error and to the neglect of quadratic terms of the coordinates of the comparison stars are negligible.

The work on the large proper-motion stars has been continued during the middle of the nights. For 126 stars in the northern hemisphere first-epoch plates have now been secured, while second-epoch plates (one year's interval) have been taken of the following four stars of exceptionally large proper motions:

Star.	P M.	No. of stars investigated.	Companions found.
	"		
Pi 2^h 123	2 34	35	1
Lal. 21185	4 77	46	0
Groom. 1830	7 06	14	0
Lal. 30694	1.66	82	0

The photovisual magnitude of the companion of Pi 2^h 123, according to Mr. Shapley, is 11.50. Assuming the parallax of the companion to be the same as that of Pi 2^h 123, its absolute photovisual magnitude is about 12.5.

During the past year five plates of the spiral nebula Messier 101 were measured and discussed for evidence of internal motion; two of these were taken by Mr. Ritchey at the 25-foot focus of the 60-inch reflector, while the other three were loaned by the Lick Observatory. The plates, combined in three pairs with intervals of 5, 9, and 14 years, were measured with the stereocomparator, which presents special advantages for the investigation of small and not easily determined displacements. The measures are differential and the possibility of setting in quick succession on corresponding points of different photographs tends to decrease the errors. On the Mount Wilson plates 87 nebulous points were measured, while 46 and 69 points were measured on the two pairs of Lick plates. The same 32 stars for comparison purposes were used throughout. After correcting the

motions of the nebulous points relatively to the stars for the proper motion of the nebula, which was found to be $+0''.005$ and $-0''.013$, the residuals gave strong evidence of internal motion. The values for individual points were resolved into components parallel to and perpendicular to the radius vector connecting them with the center; 78 rotational components are left-handed and 9 right-handed; 58 appear to be moving outward and 28 inward. The mean annual components are $0''.022$ left-handed for the rotation, at a point $5'$ from the center, and $0''.007$ outward for the radial motion. The mean resultant motion deviates but a few degrees from the direction of the branches of the spirals. Interpreted as a motion of rotation, the period would be about 85,000 years.

An improved proper motion was derived for the double cluster *h* and χ Persei with the aid of 25 cluster stars whose common radial velocity, as determined with the Cassegrain spectrograph, is about -40 km. per second. The resulting proper motion of the cluster is exceedingly small, namely, $+0''.003$ in both right ascension and declination.

STELLAR PHOTOMETRY.

The observational part of the investigations in stellar photometry by Mr. Seares and Mr. Shapley includes 767 photographs, all made with the 60-inch reflector and distributed as follows:

Selected Areas .	314	Color photograhs of nebulæ	45
Clusters .	99	Color photographs of stars	181
Variable stars	98	Miscellaneous	30

Photographic Magnitudes for the Selected Areas.

The observational part of this investigation, which is in the hands of Mr. Seares, is now approaching completion. The program for the determination of relative magnitudes on an absolute scale has been described in previous reports. As indicated by the first three columns of the accompanying table, only 30 of the magnitude-scale plates are still to be obtained. Most of the photographs required for the reduction of the relative magnitudes to a uniform zero-point have also been secured. These consist of two groups, one a series of zonal intercom-

Kind of photograph.	Photographic magnitudes		Photovisual magnitudes.	
	Required.	Obtained.	Required.	Obtained.
Magnitude scale....	460	430	111	27
Zone comparison....	228	180	72	8
Polar comparison	74	50	74	1
Totals	762	660	257	36

parisons, the other intercomparisons of certain areas with the North Pole. Each area is compared with the preceding and following area of the same zone, thus connecting adjacent regions by two plates, each with a symmetrical arrangement of exposures on the areas compared. The complete series for a zone permits a reduction of all the relative magnitudes of that zone to a common zero-point. For the final reduction to the International zero-point defined by the Polar Standards, six areas in each zone, at intervals of 4 hours in right ascension, are compared in duplicate directly with the Pole. The distribution of the polar comparisons in right ascension facilitates the adjustment of the closing error of the zones.

Of the 430 scale plates thus far obtained, 301 have been completely measured and 56 have been measured once. The reductions are complete up to and including the relative magnitudes for 70 of the areas, and for each of these a series of standards has been forwarded to Professor Kapteyn to be used in the reduction of the Selected Area Durchmusterung plates.

It is now clear that the amount of material ultimately to be accumulated will be far in excess of the original estimates, owing to the unexpected richness of the fields in and near the Milky Way. For the 70 areas whose relative magnitudes are complete the total is over 23,000 stars. A provisional investigation of the distribution with respect to the Galaxy indicates a much greater galactic condensation than that found by Chapman and Melotte. Although the totals are determined by the limiting magnitude, which varies from plate to plate, it is unlikely that the values for precisely determined intervals of brightness will modify the result.

Photovisual Magnitudes for the Selected Areas.

Photographic magnitudes can not be utilized to their full value unless photovisual results are also available. Mr. Seares and Mr. Shapley have accordingly undertaken the determination of photovisual standards for 37 of the Selected Areas—the area near the Pole and the six others in each of the six 15° zones which, in the program for photographic magnitudes, have been compared directly with the Pole. The plan is similar to that for the photographic investigation. The zonal and polar comparisons are the same in the two cases, but the observations for magnitude scale have been modified because of the longer exposures necessary with the isochromatic plate and yellow filter. Three photographs are to be made for each area: one of six 5-minute exposures with apertures of 60, 32, and 14 inches; and two others, each including exposures of 60 minutes and 5 minutes with the full aperture.

The absolute scale, to the fourteenth or fifteenth magnitude, will be established by the plates of reduced aperture. The results from the

single scale plate for each area will be corrected and strengthened by those for the adjacent areas of the same zone, which can be made available for the purpose by the zonal comparison plates. When the scales for each group of three areas have been combined into a final mean for the middle area of the group, the two plates of long and short exposure for that area will be used to extend the mean scale to the fainter stars. By this means it should be possible to reach a limiting magnitude of 16 or 17, which is but little short of that for the photographic investigation. The status of the observations is indicated by the last two columns of the table on page 246.

A Method for Determining the Color of a Star.

An expeditious and convenient method of determining the color of a star has been much desired. Estimates based upon spectral classification do not include, to an appreciable extent, the influence of intrinsic luminosity nor of any color-change produced by a possible scattering of light during its passage through space. Both color-index and effective wave-length include these factors; but color-index requires a knowledge of both photographic and photovisual magnitudes on the international scale, and hence a good deal of observational labor, while effective wave-length involves the use of an objective grating which, for a large instrument at least, is cumbersome and inconvenient.

Preliminary experiments by Mr. Seares indicate that the ratio of the exposure-times necessary for the blue and yellow light of a star to produce images of the same size can be used as a measure of its color and that the requisite observations are very quickly made. An isochromatic plate is used, with a yellow filter for the yellow image, and without filter for the "blue" image, all exposures being on the same plate. With suitable precautions for the elimination of various systematic errors, the uncertainty in the result from a single plate including two values corresponds to about 0.06 mag. in the color-index. The greater redness of stars of high luminosity, spectral type remaining the same, is easily seen in the results from even a single plate.

Distribution of Color in Nebulæ.

Experience in various fields of investigation would lead us to anticipate a lack of homogeneity in the distribution of the glowing gases of a nebula, and in many instances differences of distribution have actually been detected. For example, it has been known for some years that the distribution of the violet radiation at $\lambda 3727$, the blue-green radiation of $H\beta$ and the chief nebular lines, and the red radiation of the $H\alpha$ is very different in different parts of the Orion nebula. Many objects, however, are too faint for spectroscopic examination and special methods of investigation are required. Some preliminary experiments by Mr. Seares with color photographs promise interesting results. Color-sensitive and ordinary plates combined with filters

transmitting the violet, blue, yellow, and red regions of the spectrum have been tried. The most useful, because of the moderate exposures required, are the ordinary plate and the isochromatic plate and yellow-filter combination used in determining photovisual magnitudes. With these it has been found, for example, that the central nuclei of the spiral nebulæ Messier 51, 94, and 99 are relatively yellow, while the branches of the spirals, and especially the knots and star-like condensations scattered along them, are intensely blue. Other spirals suggest a similar result, although completely satisfactory photographs have not yet been obtained. It is not unlikely that the phenomenon is characteristic of this class of objects.

The behavior of the condensations along the branches is reminiscent of the great photographic activity of the central star in the ring nebula in Lyra. Photographs of this latter object reproduce various results of other observers, such, for example, as variations in the size and structure of the ring for light of different wave-lengths. The color-index of the central star seems to be of the order of −1.5 mag.; but the second star is less active photographically, while the two objects in the edges of the ring, just visible on ordinary plates, are strongly yellow.

In contrast to the spirals and the ring nebula, the bright planetary N. G. C. 3242 shows no important differences in blue and yellow light.

Magnitudes and Colors in Clusters.

The study by Mr. Shapley of the magnitudes in clusters has been extended to several new stellar systems. The investigations are nearing completion for the open cluster Messier 37 and for the more condensed group Messier 11, which is situated in one of the dense star-clouds of the southern Milky Way. The magnitudes in the globular clusters Messier 3, 5, 14, and 15 have been partially determined and measures on the fainter stars of the bright double cluster in Perseus have been started.

Catalogues of the magnitudes and colors in Messier 13 and Messier 67, mentioned in last year's report, and an extended discussion of the results are now in press. The earlier results, indicating the absence of light-scattering in interstellar space and the existence of giant red stars in globular clusters, have been confirmed by the investigations of the past years.

Variable Stars.

A number of miscellaneous investigations by Mr. Shapley relative to variable stars are under way or have been completed during the year. The provisional determination of the color-indices of the short-period Cepheid variables in Messier 3 indicates that in spectral type and variation of color they are closely similar to the isolated "cluster-type" variables. The similar change of color with light variation is under detailed consideration for XZ Cygni, period 11 hours, and a mean

color-curve, based on several hundred observations, will be completed within a few months. The importance of the study of such color-changes lies in the fact that a conspicuous variation in the spectral type has been found to be the underlying cause, and an analysis of these changes promises to throw further light on the nature of Cepheid variation. Some new variables, probably of the Cepheid type, have been found in the globular cluster Messier 9.

The period of the well-known eclipsing star U Cephei has been studied upon the basis of more than 20,000 photometric measures by Wendell, Chandler, and others. An interval of 33 years is covered by the observations, and throughout nearly half of this time the determination of variations in the period has a probable error of less than half a minute of time. The high accuracy permits the conclusions that a linear formula for the light elements is no longer applicable and that complicated variations in the elements exist. Orbits have been computed for the eclipsing binaries Y Camelopardalis and TT Lyræ, and revisions of several other orbits have been made. The determination of photographic and photovisual light curves for TW Andromedæ is nearly complete.

STELLAR SPECTROSCOPY.

The stellar spectroscopic work during the year has been continued by Mr. Adams along two distinct lines. The first consists of radial-velocity observations of lists of stars selected with certain definite problems of stellar motion in mind. The second consists in the development of the method of stellar classification and the derivation of relationships between spectral characteristics and the intrinsic brightness of stars. It is evident that a satisfactory method of determining absolute stellar magnitudes would, apart from other considerations, be of great importance in its bearing on radial-velocity observations, since it would at once provide the means for discussing the relationship between the motions and the probable masses of stars.

A large part of the observational work has been based on two lists of stars. The first consists of about 160 stars of visual magnitudes 7.5 to 9.0 with small proper motions; this is now about two-thirds completed. The second list is made up of the fainter stars with measured parallaxes. For many of these a camera of 18.3 cm. focal length has been employed, the radial velocity results obtained from these small-scale photographs showing a very fair degree of accordance. Numerous observations have been made on stars of known velocity, on bright stars of large and small proper motion, and on miscellaneous stars, including some of the fainter variables.

The number of photographs obtained during the year is 650, distributed as follows:

Small proper-motion stars	249
Parallax and large-motion stars	274
Miscellaneous	127

The spectrograph has been used without modification during the year. An important addition, however, is the recent installation of a new system of temperature control designed by Mr. Babcock. A series of nickel resistance-coils distributed throughout the prism-box acts in conjunction with a Wheatstone bridge and galvanometer to control the main heating-circuit in the spectrograph case. The temperature is maintained constant within less than 0°1 C., and the system has been found to be most reliable and satisfactory in its action.

Radial Velocities.

The measurement and reduction of the photographs of spectra have given determinations of the radial velocities of 141 stars based on three or more plates. Numerous other stars are nearly completed. The number of spectroscopic binaries found is comparatively small, amounting to only 8. This is due in part to the fact that the stars observed are mainly of types G, K, and M, among which the proportion of spectroscopic binaries is known to be small, and in part to the very low dispersion employed for some of the fainter stars, which prevents the detection of slight variations.

Among the more interesting results we may refer to the following:

No. of stars.	Radial velocity.
	km.
3	<100
6	75–100
11	50– 75

Most of these stars have large proper motions, and many have measured parallaxes. Two are of exceptional interest. The star B.D.+18°3423 is of type estimated as A9 and has a radial velocity of −250 km., which appears to be constant. The star recently discovered by Barnard near B.D.+4°3560, with a proper motion of over 10″ annually, has a radial velocity of −94 km. and is of type Mb. A third star, referred to in last year's report, is A.Oe. 14318, with a radial velocity of +306 km. A companion distant from it 5′ in declination has the same proper motion, parallax, and velocity, the two stars thus forming a system which moves in space at the rate of 580 km. per second.

A spectroscopic binary of exceptional interest is the eighth-magnitude star distant 80″ from Castor. The first photograph of the spectrum of this star showed double lines with a separation indicating a relative velocity of about 220 km. The spectrum is Md with bright hydrogen lines.

Classification of Stellar Spectra

The method of classification of spectra based on the relative intensities of certain lines which was developed by Mr. Kohlschütter has been employed in determining the types of the stars photographed during the year. The introduction of a few modifications into the method and a revision of the scale of intensities used in the estimates now render it possible for an experienced observer to make determinations of spectral type with a probable error of less than 0.1 division of the Harvard

system. This method of classification has been of great value in its bearing on discussions of radial velocity and investigations connected with stellar magnitudes. All of the available spectra of stars with types between F and M have now been classified in accordance with this system.

Spectral Determinations of Stellar Parallax.

It is well known that if the intrinsic brightness or the absolute magnitude of a star can be determined, its parallax may readily be derived by means of the relationship connecting apparent magnitude with distance and absolute magnitude. An investigation by Mr. Kohlschütter about two years ago showed clearly that certain lines in the spectra of the stars of the more advanced types vary in intensity with the intrinsic brightness of the stars in which they appear. The possibility of applying these results to the determination of absolute magnitudes was considered at that time.

The rapid accumulation of stellar-spectrum photographs, particularly for stars with measured parallaxes, has made it possible during the past year to investigate this question more thoroughly. A considerable number of stars of different spectral types was selected for which reliable parallax measures were available, and their absolute magnitudes were calculated with the aid of these values. The spectra of these stars were then investigated, and estimates were made of the intensities of the lines which appeared to be subject to variation with absolute magnitude. These estimates were then plotted, and equations were derived by means of least-squares solutions giving the relationship between line intensity and absolute magnitude. These equations may be used to determine the absolute magnitude of a star when the intensities of the selected lines are known. From the absolute magnitude the parallax is readily calculated.

An application of these results to 124 stars of measured parallax may be summarized as follows:

1. The average deviation of the spectroscopic parallaxes from the measured values is $0''.025$.

2. The only discrepancy exceeding $0''.1$ is in the case of a star with a parallax measured by a single observer.

3. The average value found for 25 stars with negative measured parallaxes is $+0''.03$, the largest value being $+0''.08$. The spectroscopic method gives no negative parallaxes.

4. The spectroscopic method appears to give its most accurate results for stars of types K and M. It is of little value for stars with types earlier than F5.

5. An increase in the number of measured parallaxes for very luminous stars should add materially to the accuracy of the spectroscopic method.

An application has been made of the spectroscopic method of deriving parallaxes to the question of the existence of two classes of M and later K-type stars. The investigations of Russell and Hertzsprung, based on measured parallaxes, have pointed to the conclusion that such stars are divided into two groups, one of very small and the other of very large magnitude, with an entire absence of intermediate values. In view of the small number of measured parallaxes available, it has been thought possible that this result might be due to the lack of data for the intermediate stars. The spectroscopic evidence, however, based on a larger number of stars, confirms the existence of the two groups, separated by an interval of about 7 magnitudes within which no stars have been found.

A remarkable feature of the high-luminosity or giant stars, as they have been termed, of the M type of spectrum is the abnormal intensity of the hydrogen lines. In stars like *α* Orionis and Antares these are of an intensity comparable with that in the sun, while in the low-luminosity stars of the same type they are scarcely visible. Other marked differences have been found between the spectra of the two groups, particularly in the relative behavior of the enhanced and the low temperature lines of various elements. It seems probable that quite different stages of stellar evolution are represented in these two groups.

The Intensity of the Continuous Spectrum in Large and Small Proper-Motion Stars.

A comparison of the spectra of stars of the same type of spectrum but of widely different proper motions, made about three years ago, showed that the large proper-motion stars have a relatively much more intense continuous spectrum in the more refrangible region. This effect was found to vary with spectral type, being nearly or wholly absent in the A-type stars, and increasing progressively through the F, G, and K types. A continuation of the investigation by Mr. Monk, with the aid of a large amount of additional spectroscopic material, gives results in harmony with those found previously. It has also been possible to derive a relationship between absolute magnitude and the intensity of the continuous spectrum by the aid of magnitude determinations made in the way already described.

The Spectra of Cepheid Variables.

A well-known characteristic of the Cepheid type of light variation is the excess of photographic over visual range in brightness. Periodic changes in the mean color of the radiating surface are thus indicated, and it is a natural inference that periodic changes in the spectrum must also occur. Observations by Mr. Pease in 1914 established the nature of the change for one of these variables, RS Boötis, and indicated its probable character for the whole class of Cepheids. An actual change of type was found to take place, ranging from B9 at maximum to F0 at minimum.

The adaptation of the 10-inch photographic triplet for use with an objective prism has rendered possible a systematic investigation by Mr. Shapley of all the brighter Cepheids. The spectrum of every Cepheid variable investigated, whatever its period or apparent magnitude, undergoes a periodic variation in spectral type synchronously with the change in light, similar to that observed for RS Boötis. At and near the time of maximum light the spectrum reaches its bluest stage; at the minimum it is reddest. On the average the change is nearly a spectrum interval, and appears to include successive stages which are almost if not actually identical with known types of spectra. This apparently general characteristic of Cepheid variables supports the hypothesis that the immediate cause of their light variation is to be found in periodic disturbances in their atmospheres. Further, the phenomenon of conspicuous and rapid variation of spectral type probably has considerable significance in the more general problems of the physical evolution of stars. In the furtherance of this investigation more than 300 spectrograms of Cepheids have been made. For 18 stars the spectra were found to be distinctly variable, and in no case has the spectrum of a Cepheid remained constant when its light changes.

For a further study of the differences in the spectra at maximum and minimum light, high-dispersion spectrograms of δ Cephei were made by Mr. Adams and Mr. Shapley with the 60-inch telescope. In addition to the change in spectral class, these yielded other evidence that the temperature of the gases constituting the star's absorbing envelope is higher at maximum than at minimum. At maximum the high-temperature lines, such as those of Fe, Ti, Sr, and Cr, are very strong and the low-temperature lines weak; while at minimum the reverse is the case. The radial velocity was determined both from the Fe lines showing large pressure displacements in laboratory experiments and from those showing small displacements. The difference is such as to indicate that the pressure at the radiating surface of the star is less than one atmosphere, and both in sign and amount is in good agreement with the pressure shifts shown by the solar lines.

NEBULAR SPECTROSCOPY.

Photographs of the spectra of several spiral nebulæ have been made with the small spectrograph at the primary focus of the 60-inch reflector. The most important of these is an 80-hour exposure upon N. G. C. 4594, with the slit along the axis of the spindle. A long slit was used and, with the aid of a silvered glass plate ruled at regular intervals, comparison spectra were photographed at intervals of 1 mm. on the plate. The spectrum represents approximately the central half of the nebula and is of type G5. Measurements were made on the successive spectral strips to a distance of about 2′ on either side of the nucleus. The results may be summarized as follows:

1. The radial velocity of the nucleus is +1,180 km. per second, a result in good agreement with Slipher's value of +1,100 km.

2. Within the limits of error of measurement, the linear rotational velocity varies uniformly with the distance from the nucleus. A least-squares solution gives an equation of the form $y = -2.78\,x + 1{,}180$, in which y is expressed in kilometers and x in seconds of arc. Thus at a distance of 120″ from the nucleus the rotational velocity amounts to nearly 335 km.

3. This velocity may be interpreted as representing the motion of a body rotating as a solid, or as movement along the arms of the spiral convolutions. It is opposed to the hypothesis of orbital motion of the matter producing the spectrum about a central nucleus.

4. The prominent dark streak parallel to the major axis of the spindle may be composed of cool material at the periphery of the nebula which absorbs or scatters the light. It is perhaps associated with the rapid movement of rotation or translation along the arms of the spiral.

5. The assumption that the observed radial motions for N.G.C. 4594 are of the same order as the measured angular displacements of M 101 leads to a parallax of about 0″.0002 for the former, which is similar to the average value obtained by Curtis from a discussion of proper motions.

Two photographs have been made of different portions of the spiral nebula M 33 at the Cassegrain focus of the 60-inch reflector. The first of these was on the bright knot 10′ distant from the nucleus; the second was on the nucleus itself. The condensation gives a spectrum consisting of bright lines, and the measurement of the three lines $H\gamma$, $H\beta$, and $\lambda\,5007$ yields a radial velocity of −278 km. The spectrum of the nucleus, on the other hand, is continuous with absorption lines of type A, and this type extends outward to a distance of at least 1′ on either side of the nucleus. The linear scale of the spectrum in this photograph is extremely small and measurements are difficult. The value of the radial velocity as obtained by two observers is of the order of −70 km.

PROFESSOR KAPTEYN'S INVESTIGATIONS.

Professor Kapteyn, who on account of European conditions has been unable to come to the Observatory during the year, has devoted his time mainly to two questions:

1. The first is a continuation of the investigation of the relation between the proper motions and radial velocities of stars of the spectral classes F, G, K, and M (see Report for 1915). Professor Kapteyn has found the exceedingly interesting result that the motion of the First Star-Stream is accelerated. As this would be the first directly observed evidence of the action of forces in the general stellar system, it has been deemed necessary to collect, not only for F, G, K, and M stars, but also for types B and A, all available data for both proper

motions and radial velocities of the stars of both the First and Second Streams. This more extensive investigation has brought to light contradictions which have not yet been removed, so that the acceleration of the First Stream can not yet be considered as a well established fact.

In the meantime, the work thus far done proves the continuity of the series of the B and A and the second-type stars. Hitherto, the B stars have seemed to occupy a place by themselves, inasmuch as they apparently formed but a single stream, coinciding neither in direction nor in velocity with either of the two main star-streams. In the Reports for 1911 and 1912 it was stated that some B stars at least must be regarded as members of the Second Stream. It is now found that the remainder—the overwhelming majority—belong to the First Stream. The continuity of the results for the B and A and the second-type stars appears as soon as the stars are arranged (roughly) in order of distance.

2. The second undertaking has been the completion of the investigation of the individual parallaxes of the B stars between galactic longitudes 150° and 216° and galactic latitudes −30° and +30° (see Report for 1914). This study has now been finished and can be in the printer's hands in a few weeks. It has resulted in a fairly good determination of the distances of 166 of the 168 Boss stars of spectrum B in this region. The stars in a part of the region--that round the Great Nebula (and probably belonging to the same system)—form a local group for which the parallax could not be determined in the same way as for the others. Nevertheless a fairly satisfactory result was found by a somewhat indirect method.

The paper will contain separate luminosity curves for the stars of spectrum B0, B3, B5, B0 to B2, B0 to B3, B1 to B2, B0 to B5, B5 to B9, B8 to B9, and A0 to A9.

The measurement of the Mount Wilson photographs of the Selected Areas (exposure 1^h) has been completed in the Groningen Laboratory. The reduction of the positions is practically finished. The reduction of the magnitudes will be taken in hand as soon as the standard magnitudes, now being determined at Mount Wilson, are complete.

PHYSICAL LABORATORY.

INSTRUMENTS.

An auxiliary concave-grating spectrograph constructed for use with the interferometer has proved highly efficient. The grating is of 21 feet radius of curvature and has 87,500 lines, spaced 15,000 to the inch. It is furnished with a collimated beam of light from an 8-inch silver-on-glass mirror of 21 feet radius of curvature, thus making a compact instrument free from astigmatism. The mounting is supported upon three cement piers set upon the laboratory floor, the principal parts being connected by heavy channel irons. The pier carrying the slit and

the grating supports also the interferometer and the mirrors required to project the interference pattern upon the slit. The whole apparatus is effectively protected by a cover of wood and building paper. For projecting light upon the interferometer, a concave mirror of 8 inches diameter and 2 feet focal length has been provided, thus making an entirely achromatic system. This mirror and the one of longer focus referred to above were constructed in the optical shop by Mr. Kinney. The camera accommodates plates 2.5 by 12 inches. Curvature of the field reduces the effective aperture to 8 inches in the center for flat plates, but this permits a range of 1000 A to be photographed at one exposure in the first order, in which the scale is very nearly 5 A per millimeter. For wave-lengths less than λ 4000 the second order is generally used, on account of the increased dispersion. Wave-length λ 9000 can be reached in the first order.

The vacuum arc has been modified and is now in use for producing the primary standard of wave-length—the red cadmium line. It may readily be used for an iron arc when desired.

An adapter for a measuring machine has been constructed, by means of which two rectangular coordinates may be measured without disturbing the photographic plate. For the reduction of interferometer plates covering a wide range of spectrum, this saves the continual displacement and readjustment of the plate which is otherwise necessary, and also facilitates the identification of the lines. Two more of these attachments are now under construction in the instrument shop.

A small cœlostat has been built for conveniently supplying a beam of sunlight for laboratory purposes.

Our stock of interference apparatus has been increased by the addition of an invar etalon of 15 mm. length, adjusted to about one-tenth of a wave-length.

Pole pieces of ferro-cobalt have been provided for the large magnet. For the excitation and air gap commonly used, they increase the field-strength about 4 per cent.

A rotary high-vacuum oil-pump has been purchased and installed for the study of the Stark effect.

ELECTRIC-FURNACE SPECTRA.

Mr. King's experimental work with the electric furnace has dealt with the following problems:

Variation of Metallic Spectra with Temperature.

The furnace spectra of calcium, strontium, barium, and magnesium have been studied by the method already employed for several other elements, the spectra given by furnace temperatures ranging from 1650° to 2500° C. being photographed for the range λ 2600 to λ 7200. Approximately 500 lines are included in this range for the four elements.

The photographs furnish material for the usual classification of lines according to the temperatures at which they appear and their rate of increase in intensity with rise of temperature. Certain lines are thus picked out which are useful as temperature indicators in the spectra of other sources, lines which are strong at the lowest furnace temperatures being of special interest. The fact that a considerable proportion of the lines in these spectra are known to be connected by series relations gives an opportunity to note the behavior of such lines at various temperatures. While the members of the same are affected similarly, large differences are found between separate series. The members of a triplet series of calcium were tested for a change of relative intensity with wave-length at different temperatures. As the temperature rose, the violet members of the series were strengthened to a greater degree than those of longer wave-length. This agrees with furnace observations of the principal series of cæsium and indicates a shift of the maximum with change of temperature similar to that shown by the spectrum of an incandescent solid. The close resemblance in structure between the spectra of calcium, strontium, and barium permits a comparison of the homologous lines of the three elements. Such lines are found to be affected in the same way in the furnace spectra.

Study of Banded Spectra.

The fluted spectra occurring in sun-spots which are ascribed to titanium oxide, magnesium hydride, and calcium hydride have been studied to observe the effect of oxygen and hydrogen in producing these bands in the furnace. The results showed clearly that the first-named spectrum is due to titanium oxide, the strength of the bands being controlled by the volume of oxygen which was passed directly into the furnace-tube. A sufficient supply of oxygen resulted in a complete suppression of the line spectrum, thus indicating that titanium, when fully changed to the oxide, gives the band spectrum alone. The violet members of the series of titanium oxide bands were found to become relatively stronger as the temperature rose, as in the case of series in line spectra. The use of hydrogen in the furnace with magnesium and with calcium strengthened the bands in each case, though apparently not in proportion to the supply of the gas, a small quantity of hydrogen, together with low temperature, proving very effective in producing the bands.

Spectra of the "Furnace-Flame."

Passing a stream of oxygen through the highly heated furnace-tube affords a means of producing through a wide range of temperature those effects usually obtained in flames by the ignition of various gases in the presence of oxygen. In addition to the results for titanium which have been noted, an investigation of the iron spectrum is in progress. The preliminary results indicate that the method will

be useful chiefly in the production of oxide band spectra, the relative intensity of lines in the "furnace-flame" apparently being much the same as in the vacuum furnace at the same temperature.

ANOMALOUS DISPERSION.

The electric furnace was adapted to the production of anomalous-dispersion effects by cutting away the upper portion of the tube, so that when a metal was vaporized in the trough thus formed the density gradient was equivalent to a vapor prism. Light passing through the vapor to the spectrograph gave, on each side of those absorption lines capable of showing anomalous dispersion, the familiar curved spectrum. The steadiness of the source made the use of high dispersion possible. Observations by this method were made for lines of sodium, iron, calcium, and chromium. The magnitude of the phenomenon was clearly related to the tendency of the line to reverse, and it was found that a certain temperature of the absorbing vapor is required to give the most effective prism for a given type of line. Particular attention was paid to the chromium lines λλ 4254, 4275, 4290, which show very strong anomalous dispersion. Sharp absorption lines of titanium and calcium occur close to members of this group, and tests of lines, so situated, were made for the mutual repulsion predicted by the theory of Julius. No evidence of such an effect was found, though it was sought by means of narrow lines of titanium and calcium only 0.2 to 0.6 Å from strong chromium lines. The same lines were examined for a change of wave-length possibly affecting close pairs from mixed vapors when one of the lines shows strong anomalous dispersion. The wave-lengths were found constant to 0.001 Å, whether the line of strong anomalous dispersion was present or not.

STRUCTURE OF λ 6708 OF LITHIUM AND ITS PRESENCE IN SUN-SPOT SPECTRA.

An examination of the line λ 6708 was made under high dispersion with the object of determining whether it is sometimes produced by calcium or whether it is in all cases the well-known red line of lithium, and also for the purpose of comparing its wave-length with that of a prominent sun-spot line. The observations led to the conclusion that the line is always due to lithium and that its structure differs according to the condition of the source, being apparently governed by the amount of the material present. Two distinct sets of components may be produced in either arc or furnace, or simultaneously in different parts of the arc; but an excess of vapor gives a reversed line without structure. The wave-lengths of the components were measured and their mean value was found to agree within 0.01 Å with that of the somewhat diffuse sun-spot line, thus making it fairly certain that lithium is present in the sun. λ 6708, a low-temperature furnace line, does not appear in the solar spectrum, but is apparently brought out in the spot spectrum by reason of the reduced temperature of sun-spots.

THE PRODUCTION OF CATHODO-LUMINESCENT SPECTRA.

Experiments were begun by Mr. King, and are now in progress with the cooperation of Miss Carter, in which radiation is produced by the bombardment by a stream of cathode particles of a vapor away from the path of the current, the object being to obtain metallic spectra by electrical excitation alone. The preliminary experiments with calcium vapor have given promising results, the lines H, K, and λ 4227 having been photographed, and a much richer spectrum observed visually. It is hoped to extend the method to the production of other metallic spectra.

THE ZEEMAN EFFECT.

Mr. Babcock has taken about 40 photographs of the Zeeman effect for Fe, Cr, V, and Ti. The plates have yielded separations of the components of 2,388 lines, most of which occur at least twice, however, so that the number of new lines available is very much less than this. All the values of the separations have been reduced to a standard field and tabulated in order of wave-length for each element. The discussion of all the material thus accumulated has had to be deferred, but it is planned to use it for a further examination of the correspondence between the Zeeman effect and other agencies known to affect the wave-length of spectrum lines.

STANDARDS OF WAVE-LENGTH.

A few plates have been taken by Mr. Babcock with the interferometer in connection with the 13-foot Littrow spectrograph for the determination of wave-lengths of carbon and calcium lines in terms of the iron secondaries. The values obtained are in excellent agreement with those made by means of the grating.

Of the 32 photographs with the new interferometer apparatus now available, a few have no measurable exposures on the red cadmium line, but about one-half have been measured and reduced. The 5, 7.5, 10, and 15 mm. etalons have been used, the first for a majority of the plates. In the region λλ 4100–5050 about 150 iron lines have been measured in terms of the red cadmium line, but the final wave-lengths await the evaluation of small corrections still to be applied. The method finally adopted for the reduction of the plates involves the measurement of the linear diameters of five rings for each line and the calculation of the fractional order of interference by a simple least-squares solution of the observational equations, which is carried out very rapidly. The uncertainty in a single determination of the order of interference found in this way for good lines is about one part in four or five millions, *i. e.*, about 0.001 Å in the wave-length. The method entirely avoids the measurement of focal lengths of lenses or mirrors.

Besides the redetermination of secondary standards and the addition of new lines to the list of secondaries, work in progress includes a comparison of wave-lengths of selected lines taken from the 220-volt arc recommended by the International Committee with those taken from the Pfund arc at 110 volts and also from an arc having one terminal of carbon. Our program includes the evaluation of wave-lengths obtained from the iron arc *in vacuo*, both by direct comparison with the red cadmium line and by reference to the spectrum of the arc under normal pressure. The iron lines from the vacuum arc are extremely sharp and large numbers of them can easily be obtained with intensity sufficient to serve as secondary standards.

COMPUTING DIVISION.

The Computing Division has remained throughout the year under the direction of Mr. Seares.

For some weeks Miss Brayton was engaged with the reductions of a group of 34 photometric plates for the Selected Areas, but latterly has been occupied exclusively with the work in stellar spectroscopy. She has measured and completely reduced 391 spectrograms and has done miscellaneous checking and work on the preparation of reduction tables for spectrograms.

Miss Carolyn Burns has continued her work in stellar photometry. 76 Selected Area plates have been measured and reduced, and miscellaneous reductions relating to other plates have been finished.

Miss Margherita Burns joined the Division on January 1 and has devoted her time to the work of the physical laboratory. The screws of three measuring machines have been tested, measures and reductions relating to 17 Zeeman plates have been made, and much miscellaneous work connected with the interferometer observations by Mr. Babcock has been done.

Miss Burwell still gives the greater part of her time to the study of stellar spectrograms, 470 plates having been measured during the year. An extended series of estimates of line-intensity for the determination of spectral type and absolute magnitude has also been made.

Miss Davis has spent half of the time upon the photometric investigations of Mr. Shapley. She has measured about 125 photographs of variables and clusters and has reduced 40 others, besides plotting extended series of observations on several of the cluster-type variables. Her remaining time has been given to the parallax and proper motion work of Mr. van Maanen. Least-squares solutions were affected for 15 parallax fields and assistance was given in the reductions for determining the internal motions of M 81 and M 101.

Mrs. Fretter continued to assist with the work of the physical laboratory until the date of her resignation on January 1.

Miss Joyner has given all her time to stellar photometry; 113 scale plates for the Selected Areas have been measured and reduced and measures and partial reductions were made for 45 photographs for star colors.

Miss McClees has measured and reduced 8 photographs of sun-spot spectra and 20 photometric plates of Selected Areas. The greater part of her time has been devoted to miscellaneous computing.

Miss Miller has assisted with the solar investigations of Mr. St. John. She has measured 20 sun-arc plates and determined the wave-lengths on 10 separate photographs of solar and arc spectra for comparison with the results from the sun-arc plates. She has also measured several plates for the Einstein effect and 14 plates for the separation of close pairs of lines.

Mrs. Monk continued with the work in stellar spectroscopy up to the date of her resignation on June 1; 600 spectrograms were measured and the greater part of them reduced. Reductions to the sun and star constants were calculated, the screw of one measuring machine was investigated for periodic error, and four test plates for the figure of the 100-inch mirror were measured.

As in the past, Miss Richmond has given her time mainly to stellar photometry; 119 Selected Area photographs were measured and reduced in addition to 45 plates which were measured for star colors. Test plates for the 100-inch mirror and spot-spectrum photographs were also measured.

Miss Shumway has continued to serve as recorder and computer in connection with the stellar spectroscopic work.

Miss Stone joined the Division on June 1 to fill the vacancy caused by the resignation of Mrs. Monk.

Miss Ware has given much time to the measurement of the sun-arc photographs and the separate plates of sun and arc spectra taken for the investigation of the influence of anomalous dispersion. She has also measured the separation of close pairs of lines on a long series of plates forming a part of the investigation of the systematic errors affecting measures of this kind. A few solar-rotation plates have been measured and a number of microphotometer curves have been registered.

Miss Winn joined the Division on August 1 to fill the vacancy caused by the resignation of Miss McClees.

Miss Wolfe has continued the reductions relating to the sun's general magnetic field. Results for 21 additional days, involving 63 least-squares solutions, are now available. A preliminary least-squares reduction for rotation period and inclination of the magnetic axis has also been completed. Miss Wolfe has also done much miscellaneous computing, a good deal of photographic work, including prints of solar photographs and charts of Selected Areas, and for six months served as librarian.

Several members of the Division, notably Miss Carolyn Burns, Miss Davis, and Miss Richmond, have assisted with checking and proof-reading.

Mrs. Longacre also assisted with the editorial work and remained in charge of the library until January. Her resignation took effect on March 1, and Miss Connor was appointed to fill the vacancy on July 15. The accessions of bound volumes number 365; 205 by purchase, 138 by binding, and 22 by gift. The total number of volumes is now 4,256.

CONSTRUCTION DIVISION.

DRAFTING AND DESIGN.

Mr. Pease has continued in charge of drafting and design, and has paid much attention to the erection of the 100-inch mounting and the inspection of parts made in outside shops. Mr. Nichols has acted as chief draftsman since the first of January. About half of the year has been spent on 100-inch telescope drawings and the remainder on other work.

Among the 100-inch telescope drawings completed are those of the jib crane, shutter mechanism, observing platform wind-screen, optical system for reading circles from main operating desk, right-ascension direct setting circle, and temperature control for the mirror. Drawings for other instruments include:

Camera for 10-inch portrait lens, with double-slide plate-holder (14 by 17 inches) and numerous other attachments.
Alterations in the Snow telescope, including new spectrograph pit, cœlostat and concave-mirror slow motions, and 30-foot spectrograph with all its attachments.
Short-focus camera for Cassegrain focus of 60-inch telescope.
Adapter for registering photometer on 6-inch refractor.
Additions to measuring machines.
Concave-grating spectrograph of 3.5 m. focus.

Many drawings have also been made for charts and illustrations.

WORK OF THE OPTICAL SHOP.

The work of parabolizing the 100-inch mirror has been brought by Mr. Ritchey to successful completion. For many months, as the figure was gradually brought nearer to a true paraboloid, daily optical tests were made both at the center of curvature and at the primary focus. The focal tests involved the use of the 60-inch plane mirror which was made here for this purpose, and the close agreement and consistency of the daily results secured by the two methods gave much satisfaction and confidence in the outcome.

In general, the tests at the center of curvature were found to be most useful in determining the total amount of parabolization. In these, successive zones of the surface are examined, one after another, from

the edge to the center, and the radius of curvature of each is determined by the knife-edge test and compared with the theoretical value. Under the best conditions of air in the testing-room it is possible to determine the radius of curvature of a zone within 0.001 inch (0.025 mm.).

The tests made at the focus of the paraboloid in combination with the 60-inch plane mirror are invaluable for detecting and correcting slight zonal errors of surface. In this test any 60-inch circular area of the 100-inch surface can be seen at one time, and the aim of the figuring is to eliminate all high or low zones shown in relief and to bring the whole 100-inch surface to such a condition that all parts, as seen during the test, appear perfectly flat. By a combination of both tests, especially in the last critical stages of figuring, we attain a degree of certainty, and consequently a degree of accuracy of surface, which can not be obtained by either test alone.

After the figuring of the mirror had been completed, a photographic test by the Hartmann method was undertaken, both to check the visual tests and to provide a permanent record of the surface. For this purpose a large diaphragm was constructed with openings 2 inches in diameter along axes making an angle of 45° with one another. The photographs were taken in pairs on either side of the center of curvature of the central zone of the mirror. Since the light source was stationary, the differences in the measured radii of curvature for the several zones are twice as great as in the visual test, in which the light source is moved for each zone.

The results of the measurement of three pairs of photographs are given in the accompanying table:

Radius of zone.		Center of curvature.			Primary focus, O–C
		Observed radius.	Computed radius.	O–C	
Inches.	*mm.*	*mm.*	*mm.*	*mm.*	*mm.*
8	203	25783 33	25782 60	+0 73	+0 18
10	254	25784 08	25783.50	+0 58	+0 14
16	406	25787 33	25787 41	−0.08	−0 02
18	457	25789.11	25789 11	0.00	0 00
24	610	25794.96	25795.42	−0.46	−0.12
26	660	25797.35	25797.92	−0 57	−0.14
32	813	25806.48	25806.63	−0 15	−0.04
34	864	25809 81	25809.94	−0.13	−0.03
40	1016	25821.02	25821.06	−0 04	−0.01
42	1067	25824 93	25825.16	−0.23	−0.06
48	1219	25838 73	25838.69	+0.04	+0 01
49½	1248	25841.80	25841.43	+0.37	+0.09

When in use in the telescope, the 8-inch zone will be covered by the projected area of the Newtonian and the convex mirrors. The largest deviation of the observed from the theoretical focal length for any of the remaining zones is 0.14 mm., or about one part in 92,000.

The focal length of the 100-inch mirror is approximately 507.5 inches (12.88 m.), the clear aperture being very nearly 101 inches (2.57 m.). The depth of the curve is about 1.25 inches (31.8 mm.) at the center; the thickness of the finished glass is 12.75 inches (323.8 mm.) at the edge. At the center, where the difference is greatest, the depth of the finished paraboloid differs from that of the nearest spherical surface (to which the glass was brought in preparation for parabolizing) by almost exactly 0.001 inch (0.025 mm.). The weight of the finished glass is very nearly 9,000 pounds (4,082 kg.).

The work of parabolizing was done almost entirely with the large polishing machine and by the use of two polishing or figuring tools of 90° sector form, one of 850, the other of 415 square inches area (the area of the 101-inch glass surface is about 8,012 square inches); at least 95 per cent of the work was done with the larger tool.

A system of progressive positions or settings of the tool, and of progressive strokes also, was used, similar to that devised while figuring the 60-inch mirror. The system was greatly elaborated in this case, however, and was used from the beginning of the parabolizing, so that a great amount of experience was acquired before the work reached the final and critical stage. This method made it possible to keep the curve smooth at all stages of the work; in other words, it enabled the opticians, from the beginning of parabolizing, and in each successive day's figuring, to keep the percentage of the change of radius of curvature, as compared with the total theoretical change, very nearly correct for each zone. As a result it was possible to bring the parabolizing almost to completion by the use of the machine and the large figuring-tools alone. Less than 20 hours' work with small figuring-tools used by hand was required at the very last stage to soften down several slight protuberant zones which were too narrow for treatment with the machine.

Silvering the large mirror was accomplished without difficulty. The large polishing machine was utilized, as it permits rocking the mirror for the various operations of silvering, and also tipping the mirror for pouring off the solutions, both operations being accomplished by the motor-driven mechanism. The work required 32 ounces of silver nitrate; about 150 gallons of distilled water were used in the entire process; 35 gallons of distilled water were required to fill the concavity, and to this 9 gallons of dilute silver solution and 9 gallons of dilute reducing solution were added. The time required for the deposition of the silver was 15 minutes. Burnishing of the silver film was done with the large polishing machine and a cushioned burnishing tool 34 inches in diameter, covered with six selected chamois-skins.

In addition to the work on the large mirror, much has been done on the two convex mirrors for the same telescope, and on the apparatus, both mechanical and optical, for testing these mirrors daily, in com-

bination with the finished 100-inch paraboloid and the 60-inch plane mirror while they are being hyperbolized. One of these mirrors is 28.75 inches (730 mm.) in diameter and over 6.5 inches (165 mm.) thick. It has a radius of curvature of 346.7 inches (8.81 m.), and gives, with the 100-inch mirror, an equivalent focal length of 1,607 inches (40.8 m.). The other convex mirror is 25 inches (635 mm.) in diameter and 5.5 inches (140 mm.) thick, with a radius of curvature of 274.9 inches (6.98 m.) and gives, with the 100-inch mirror, an equivalent focal length of 3,011 inches (76.5 m.). The convex mirrors are now fully polished, each to the nearest spherical surface, and are ready for hyperbolizing.

WORK OF THE INSTRUMENT SHOP.

The instrument shop (Mr. Jacomini, chief instrument maker; Mr. Ayers, foreman) has been very busy throughout the year. The ruling-machine has absorbed most of Mr. Jacomini's time in the extensive work of final adjustment and testing and the correction of difficulties encountered with the ruby-steel end-thrust bearing. We hope to overcome these by lightening the grating-carriage and by refiguring the ruby and improving its mounting. The first grating completed contains 95,000 lines, covering an area of 127 by 160 mm. A careful visual and photographic test of this grating, made by Mr. Babcock, shows that its resolving power is high, though some ghosts are present. The systematic use of the machine should soon be followed by still better results.

The numerous parts of the 100-inch telescope mounting have occupied more than half the time of the instrument shop, but other important additions to the equipment have been made. These include parts or attachments for the 10-inch photographic refractor, 60-inch reflector, Snow telescope, 75-foot spectrograph, 30-foot spectrographs of the 60-foot tower and Snow telescopes, 13-foot spectroheliograph, auxiliary concave-grating spectrograph for laboratory, focal-plane and Cassegrain spectrographs and 8 by 10 plate-carrier for 60-inch reflector, measuring-machines, apparatus for optical work on the 100-inch mirror, apparatus for Stark and Zeeman effects, auto truck and instrument repairs, and miscellaneous work of various kinds.

ONE-HUNDRED-INCH TELESCOPE.

In view of the conditions prevailing at the Fore River works, it seemed undesirable to provide for a complete assembly of the 100-inch telescope mounting in the factory yards. The more important portions, however, such as the mercury tanks and floats, the sections of the polar axis, and the main bearings, were fitted together and tested individually, after which all parts of the mounting were shipped to Pasadena. The four sections of the tube, being too large for railroad clearances, were sent by steamship to Los Angeles Harbor. Through the cooperation of the International Motors Company, a 6½-ton Saurer

truck was placed at our disposal and the difficult work of transportation up the mountain road was commenced last autumn. Several of the larger pieces weigh over 9 tons, but the transportation was carried out without difficulty and the entire mounting, with the exception of the tube sections and the mirror cell, was housed within the 100-inch telescope dome before the opening of the rainy season.

In the Pasadena shop the work on the smaller parts of the mounting has proceeded rapidly under the direction of Mr. Ayers, and is now so far advanced that no delay from this cause is to be expected in the complete erection of the instrument. The shop work has included the right-ascension and declination slow and fast motions, the coudé mechanism, portions of the insulating cover about the mirror cell, the declination counterweight system, and many other auxiliary attachments.

The 100-inch telescope dome is now fully completed and painted and the mounting is being erected by Mr. Jones and Mr. Sherburne. The auxiliary features of the dome, including observing-platform, jib crane, 10-ton traveling crane, and wind screen have been installed, and the two cranes are being utilized in the erection work. The mirror elevator is partially completed. The electric wiring of the dome and instrument mounting is nearly finished. As 35 electric motors are involved in the motions of the various parts of the telescope and dome, this has been a task of very considerable difficulty. All of this work of wiring, as well as the construction of six switch-boards, has been carried on by Mr. Dowd, engineer in charge of the power-plant.

OTHER CONSTRUCTION WORK ON MOUNT WILSON.

With the transfer of the 5-foot spectroheliograph to the 60-foot tower and the increasing demands upon the time of this instrument, it has seemed desirable to adapt the Snow telescope to spectroscopic work of high precision. Accordingly a pit 35 feet deep has been constructed by Mr. Jones at a distance of 60 feet from the concave mirror, and a vertical spectrograph, of type similar to that used in the two tower telescopes, is being built in the Pasadena shop for work within this pit. Slow-motion motor controls are being installed on the cœlostat and concave mirrors to facilitate guiding during the exposures.

Other construction work on the mountain has included the installation of a concrete conduit system to carry electric cables between the power-house and the tower telescopes, 60-inch, and 100-inch domes. Work has been commenced on a new telephone line to follow the route of the mountain road. The present line, cheaply built eleven years ago, follows a route very difficult of access in stormy weather, and it has been impossible to maintain uninterrupted service during the winter months. The portion of the line already installed will obviate some of the most serious difficulties in this respect.

All of the more important buildings on the mountain have been painted during the year, including the Snow telescope building, the two towers, and the two large domes. General repairs have been carried on as usual in order to maintain the instruments in a high state of efficiency.

SUMMARY.

The chief results of the year may be summarized as follows:

Many dark hydrogen (Hα) flocculi, including "filaments," have been identified with prominences.

Stereograms of the flocculi, after eliminating certain false effects, are useful in showing their relative levels.

A new photographic map of the sun-spot spectrum, on a scale of one centimeter to the angstrom, has been prepared for the region λ6000 to λ6450.

Observations of the polarization phenomena of Zeeman triplets in spots near the sun's limb suggest that the lines of force spring from a level below that of the region encircling the penumbra.

Bipolar sun-spots in the northern or southern hemisphere, irrespective of latitude, are opposite in polarity to the bipolar spots of the corresponding hemisphere observed before the recent sun-spot minimum.

The hydrogen vortices associated with sun-spots nevertheless retain the direction of rotation which they showed before the minimum.

Comparative studies of solar and vacuum-tube spectra hitherto yield no reliable evidence of the existence of electric fields in sun-spots.

The approximate inclination and period of the sun's magnetic axis, as deduced from photographs covering 37 days, are as follows:

$$P = 31^{d}.51 \pm 0^{d}.62 \qquad i = 5^{\circ}.2 \pm 0^{\circ}.5 \qquad t_0 = 1914 \text{ June } 25^{d}07 \pm 0^{d}43$$

The measurement of the separations of close pairs of lines in the solar spectrum shows that such determinations are subject to systematic errors. These errors depend upon the intensity of the continuous spectrum between the lines, the observer tending to make the separation larger when the intensity between the lines is reduced below that of the general background. The photographs taken with the highest resolving power and showing the finest definition give the smallest values for the separations.

Measurements of close pairs of solar lines show systematic differences between Rowland's values and those obtained at Mount Wilson, the latter being the smaller. These differences depend on the amount of the separations and are largest when the lines are very close to one another. The Rowland errors cease to be systematic when the separation is about 0.5 Å.

These errors appear to account fully for the apparent effect of mutual influence among the Fraunhofer lines derived by Albrecht from a comparison of results in Rowland's table with the International

wave-length determinations for the lines of the arc spectrum of iron. Direct measurements made at Mount Wilson show that for 45 selected pairs of lines the separation, within the limits of error of measurement, is identical in the sun and arc spectra.

The sun-arc displacements, as deduced from several hundred lines, are the same for those with companions as for free-standing lines.

The influence of an electric field (Stark effect) upon the spectrum of lithium and calcium has been investigated in the laboratory. The longitudinal components in the case of lithium are clearly polarized, differing in this respect from those of hydrogen and helium. The H and K lines of calcium show longitudinal components with a separation comparable to those for H, He, and Li, but are not polarized. Negative results with the dispersion employed have been found for Fe, Ni, Al, Mg, Zn, and Sr.

Direct photographs of Jupiter and Saturn made with the 60-inch reflector, using color filters transmitting infra-red, yellow, violet, and ultra-violet light, show marked differences in the distribution of the light of different colors on these planets. In the case of Jupiter, numerous differences are found in the appearance of the dark and bright belts, the former being more prominent in the light of longer wave-length.

Photographs of Saturn show remarkable variations of the markings in light of different colors. A broad dark belt surrounding the planet's equator is visible in violet and ultra-violet light which is absent in yellow light, and the same applies to a dark polar cap of considerable size. Density measurements with a Hartmann microphotometer fully confirm these results.

The investigation of the probable relationship between linear motion and absolute magnitude for stars of several spectral types has been continued during the year.

The continuity in the series of the B and A, and the second-type stars, has been established. The great majority of the B stars are found to belong to the First Stream, which seems to be accelerated.

The determination of the individual parallaxes of the brighter B-type stars between the limits galactic longitudes 150° and 216° and galactic latitudes $-30°$ and $+30°$ has been completed.

Several long-exposure photographs, mainly of spiral nebulæ, have been obtained during the year.

Measurements upon five photographs of Messier 101, representing intervals of 5, 9, and 15 years, give strong evidence of internal motion. The results agree in indicating a motion, at a distance of 5′ from the nucleus, of 0″.022 annually in a tangential direction, and of 0″.007 in a radial direction outward. These results may be explained by a rotational motion, or by movement outward along the arms of the spiral. If interpreted as a rotation, the period would be about 85,000 years.

Complete parallax determinations have been made for 15 stars. The mean probable error of a final parallax is ±0″.006.

With the aid of stars having a common radial velocity, an improved proper motion of the double cluster *h* and χ Persei has been derived.

The plates for photographic magnitudes in the Selected Areas are 86 per cent complete, and relative magnitudes have been determined for 70 of the 115 regions. Observations for photovisual magnitudes in 37 of the areas have been begun.

It is found that the ratio of the exposure-times necessary for the blue and yellow light of a star to produce images of the same size is a reliable measure of the star's color. The precision is sufficient to reveal the influence of abnormal luminosity upon color.

Color photographs of certain spiral nebulæ show that their central nuclei are yellow, while the branches are very blue.

A continuation of the investigation of magnitudes and colors in clusters confirms the presence of giant red stars in the globular clusters and the negligible value of light-scattering in the direction of the Hercules cluster. Catalogues of magnitudes and colors for this cluster and for Messier 67 have been completed.

The study of magnitude and color changes of variable stars has been continued, notably for the variables in Messier 3, and for XZ Cygni and TW Andromedæ. Variations in the elements of U Cephei have been investigated and the orbits of several eclipsing stars have been calculated.

The radial velocities of 141 stars have been determined from three or more spectrum photographs. Five stars show velocities exceeding 100 km.; one with a velocity of −250 km. is of type A9.

The cluster variable XZ Cygni has a motion of about −150 km., with a moderate variation of velocity. Its spectrum varies from about A2 at maximum of light to A8 at minimum.

The star Boss 46 is a spectroscopic binary of type B3 with double lines. The maximum relative velocity so far observed is about 400 km. The H and K lines show little or no variation, but the orbit is still under investigation. The period appears to be of the order of two days.

The spectrum of Barnard's large proper-motion star is Mb and it belongs to the dwarf class of M stars, with the spectral characteristics peculiar to this class. Its radial velocity is about −94 km.

An investigation of the spectral relationships between stars of different absolute magnitudes has been published, and a method has been derived for obtaining parallaxes from spectral peculiarities. An application to 124 stars of measured parallax gives values in satisfactory agreement with measured results, the average deviation from the latter being 0″.025, with distinctly better agreement for parallaxes of highest weight. The method apparently may be applied both to stars of high and low absolute luminosity, and hence to the determination of very small parallaxes. It seems to be most accurate in the case of the K and M-type stars, and least for the F stars.

An application to the M and later K types gives marked evidence of the two groups of giant and dwarf stars, no M stars occurring within an interval of about 7 magnitudes. Further, in the giant stars the hydrogen and the enhanced lines are relatively strong and the low-temperature lines are faint; in the dwarf stars the reverse is the case.

The continuous spectrum of large and small proper-motion stars studied with the aid of absolute magnitude determinations confirms previous results. The violet region is relatively stronger in the low-luminosity stars, the relative intensity being nearly proportional to the absolute magnitude.

The spectrum of the short-period Cepheid RR Lyræ varies between types B9 and F2 during the 13-hour period of the light variation. A detailed study of all existing photometric measures shows oscillations in the range of variation and in the shape of the light-curve, as well as complicated changes in the length of the period.

Periodic variations in the spectrum of δ Cephei are shown by objective-prism spectra and by high-dispersion slit spectrograms. The latter also show numerous differences in the spectra between maximum and minimum of light which indicate a temperature variation as well as a probable change of pressure in the star's atmosphere.

Seventeen Cepheid variables have been found from objective-prism photographs to vary in spectral type with variation in light.

The radial velocity of the nucleus of the spiral nebula N. G. C. 4594 is +1,180 km., a result in good agreement with that obtained by Slipher.

Measurements extending to a distance of 120″ on either side of the nucleus show a rotational velocity, or a relative motion along the arms of the spiral, of 335 km. This motion varies uniformly with the distance from the nucleus.

A parallax of the order of 0.″0002 is obtained for the nebula on the assumption that the radial motions correspond to the angular displacements observed in Messier 101.

The spectrum of the nucleus of the spiral nebula Messier 33 is continuous with absorption lines of type A. A condensation at a distance of 10′ from the nucleus shows a bright line spectrum, and a relative velocity between nucleus and condensation of about 200 km. is indicated by the measurement of the photographs.

From a study of electric-furnace spectra of calcium, strontium, barium, and magnesium clear evidence has been obtained of a relative strengthening of the violet members of a series at higher temperatures in the case of both line and band spectra.

The banded spectra occurring in sun-spots and ascribed to titanium oxide, magnesium hydride, and calcium hydride have been obtained with high intensity in the furnace, and the conditions most favorable for their production have been studied.

A current of oxygen, passed through the electric-furnace tube, gives a means of producing flame spectra over a wide range of temperatures, the maximum temperature probably being higher than that obtained in the regular flames.

A study of anomalous-dispersion phenomena has been made with the electric furnace, both with regard to general effects and to the possible change of wave-length of a line very close to another line which shows strong anomalous dispersion. These tests and the use of mixed vapors in the furnace gave no evidence of the predicted repulsion between close lines.

The complex lithium line $\lambda 6708$ has been photographed with high dispersion in furnace and arc spectra and its components have been measured. The close agreement with the wave-length of a prominent sun-spot line offers evidence of the presence of lithium in the solar atmosphere.

Preliminary experiments have shown the possibility of bringing metallic vapors to luminescence by the impact of cathode particles in high vacuum.

Additional measures of the Zeeman effect have been made for 2,388 lines in the spectra of Fe, V, Cr, and Ti.

Interferometer determinations of wave-length with respect to the red cadmium line have been partially completed for 150 iron lines in the region $\lambda\lambda$ 4100–5050.

Tests of the 100-inch mirror, now completed and silvered, show a maximum error of focal length for any zone of about one part in 92,000 as compared with the theoretical value.

The 100-inch reflector dome has been completed and painted, and over one-half of the mounting is erected. The observing-platform, 10-ton traveling-crane and cage hoist, shutter mechanism, and jib crane have been installed, together with a portion of the mirror elevator. The Snow telescope has been remodeled for use in conjunction with a vertical spectrograph of 30 feet focal length, for which the pit has been completed. About 900 feet of concrete conduit for electric wires have been constructed, a portion of which contains the heavy cables furnishing power to the 100-inch telescope and dome. Many test rulings and a preliminary grating of very promising quality have been made with the ruling engine.

NUTRITION LABORATORY.*

FRANCIS G. BENEDICT, DIRECTOR.

The Nutrition Laboratory was founded primarily for the study of the basic laws of vital activity with special reference to the transformations of matter and energy in the human body. While a large number of biological problems are studied by making use of animals and domestic fowl and applying the results to the physiology of man, in the final use of such data the special physiological conditions obtaining with man should invariably be taken into consideration. This makes observations directly upon man of the highest value to human physiology. Most observations on animals may readily be made in laboratories without extraordinary equipment; the conditions for some experiments on man are likewise easily met by most university laboratories, but the extended study of many problems in human physiology, requiring the use of several subjects, can rarely be attempted outside of special research laboratories. Consequently, laboratories possessing unusual equipment for physiological research are under a moral obligation to contribute, as far as possible, directly and primarily to our knowledge of human physiology and to use the lower animals chiefly in supplementary problems and when the inherent difficulties in using men as subjects considerably restrict the lines of inquiry that may profitably be followed.

Data on animals may readily be accumulated by a laboratory assistant under supervision, but the serious problem of observations on human individuals necessarily limits definitely the responsibility to the trained observer. The researches in the Nutrition Laboratory have gradually developed until finally the Director's responsibility for its scientific work is shared equally with Doctors H. M. Smith, T. M. Carpenter, and W. R. Miles. Central editorial and computing bureaus under the charge of Miss A. N. Darling and Mr. W. H. Leslie, respectively, aid in the general preparation of material for publication.

This administrative plan insures the completion of problems begun, avoids the difficulties of non-resident attempts to prepare previously accumulated material for publication, and provides a systematic method for both the publication of results and the treatment of material. This does not imply by any means a similarity of treatment in detail and the arbitrary rulings of an editorial bureau, as each of the four responsible investigators assumes full responsibility not only for the accumulation of experimental evidence but for the preparation of his report. On the other hand, central computing and editorial

*Situated at Boston, Massachusetts.

bureaus do secure uniformity in the general methods of treatment and tabulation—a factor of prime importance in the consecutive presentation of correlated researches.

Since the correlation of research is of fundamental consequence, continuity in the development of thought and line of attack in the various problems is highly desirable. In perhaps no other way does the Nutrition Laboratory differ more from the usual university laboratory than in this general plan. Resident voluntary assistants and research cooperators of proved merit are, of course, welcome, but intermittent, temporary workers almost invariably require more administrative care than several well-planned and continuous researches carried out by the regular staff and collaborators. In many university laboratories the temporary assistant and volunteer worker must be the main reliance for research work; but it is clear from past experience that, in a research institution like the Nutrition Laboratory, such work is usually fragmentary, and that any value it may have is by no means commensurate with either the administrative or editorial time devoted to it. In a laboratory such as this the backbone of progress is coordinated, correlated research.

As an example of the desirability of coordination in research we may cite the alcohol program which was prepared in this laboratory and issued January 1, 1913. This program was not intended to be the statement of an experimental inquiry for the completion of which the Laboratory is obligated, but was presented with the hope that it would suggest profitable lines of articulated research in a considerable number of laboratories and institutions whose facilities and interests particularly fit them for undertaking the various problems. While the Nutrition Laboratory is committed to a continuation of the investigation, and while definite arrangements have been formulated to make the alcohol investigations, either on the physiological or on the psychological side, a substantial part of each year's work, it is inconceivable that any one or a dozen laboratories can adequately complete this program in a decade.

No major projects in addition to those outlined subsequently in this report are contemplated. With the present staff but slight modifications and additions should be needed to carry out, for several years, well-coordinated series of researches. As the period of organization and of the development of technique and novel apparatus necessary for studying the phases of human physiology which this laboratory emphasizes, namely, bio-energetics, is practically over, the present administrative problem is so to adjust the research work as to meet the demands of pure physiology on the one hand and those of pathology on the other. Since little in the way of precedent was available to assist materially in studying many points, it is perhaps not surprising that seven years have been required to adjust the Laboratory to this definite experimental plan.

ADDITIONS TO EQUIPMENT.

During the war in Europe it has not been possible to receive scientific apparatus from Germany; the Nutrition Laboratory, therefore, in common with numerous other research laboratories, has suffered for the lack of material purchased before the outbreak of hostilities, but, as yet, unobtainable. Several important instruments have been secured in this country, however, and the construction of scientific apparatus by our Laboratory construction staff has been unusually extensive.

APPARATUS FOR THE PSYCHOLOGICAL LABORATORY.

A string galvanometer with combination resistance and standardizing outfit, both pieces of apparatus designed by Dr. H. B. Williams, of the Department of Physiology, Columbia University, also an automatic Weule arc lamp, have been installed in the psychological laboratory. This new model of string galvanometer is of great practical advantage to workers in the United States, particularly at the present time, for with the imported instruments the breakage of strings and delay in replacement has been, even in times of peace, most uneconomical. The Williams galvanometer supplies an exact physical instrument, inasmuch as equal increments of current will give equal increments of deflection for 8 cm. on either side of the base-line with a magnification of 900 diameters.

An Ives-Cobb visual acuity object has been constructed for us at the Nela Research Laboratory, supplemented by the necessary apparatus, and mounted for use as a testing instrument.

A pendulum contact-breaker of the general form devised by Lucas has been constructed in the Laboratory shop. The present instrument automatically closes the contacts that have been struck open by the rapidly falling pendulum. The interval between the opening of the switches is continuously variable and its duration for any setting is accurately known. The device is used as a stimulus regulator when determining the sensory threshold for electrical stimulation.

RESPIRATION CHAMBERS FOR COLD-BLOODED ANIMALS.

The researches at the New York Zoological Park necessitated the construction of several respiration chambers of various sizes for experimentation with cold-blooded animals. As animals of this class have an extraordinarily low metabolism, it was necessary to select the largest ones available for the experiments. Accordingly a chamber was built of sufficient size to contain a Galapagos tortoise weighing 132 kg. Subsequently a recessed cover was designed and employed which considerably reduced the volume of the chamber and permitted its use for a 16½-foot Indian python and a 7½-foot alligator. To minimize the attention and labor required in these time-consuming experiments with cold-blooded animals, a valve device was constructed to connect

two respiration chambers with a single universal respiration apparatus. It was thus possible to conduct simultaneous experiments with a tortoise in one chamber and a Cuban boa in the other, and to secure accurate observations in 24-hour periods.

CLINICAL RESPIRATION CHAMBER.

As a result of the development of a clinical respiration chamber, which has been in progress for several years past, a complete apparatus was installed in the New England Deaconess Hospital. During the summer a research laboratory was constructed by the authorities of the hospital in the basement of the building for the use of the Nutrition Laboratory in respiration researches. The clinical respiration chamber is, at the moment of writing, being transferred to this new research laboratory.

INFANT RESPIRATION CHAMBER.

The conclusion of our accumulation of data with infants from birth to 1½ years of age has led to the study of infants of approximately 2 years of age, thus requiring the use of a larger respiration chamber to accommodate the larger body of the infant. Such a chamber has been constructed and is being regularly employed for studying the older infants in the Massachusetts Wet Nurse Directory.

RESPIRATION CALORIMETER FOR SMALL ANIMALS.

For some time the Laboratory has been endeavoring to develop a respiration calorimeter for small animals which would overcome the objection to many existing types, especially as to the large mass of metal frequently employed. After several years of unsuccessful experimentation a type was devised during the past year which has proved especially sensitive. This apparatus has already been used for a study including the measurement of the gaseous metabolism and of the direct and indirect calorimetry of fasting geese.

Thanks to the personal interest of Professor Elihu Thomson, of the General Electric Company, of Lynn, two meters were designed and constructed for use in connection with this calorimeter. These meters possess certain special features for measuring the amount of electrical energy actually delivered. The successful construction of the meters made possible the completion of the new respiration calorimeter.

LARGE RESPIRATION CHAMBER.

In the original design of the Nutrition Laboratory space was provided in the calorimeter laboratory for the construction of a large respiration chamber which would permit the study of the gaseous metabolism of a number of individuals simultaneously or of a few individuals working to the limit of human endurance. The construction of this apparatus was deferred until the decision was made as to whether or not calorimetric

features should be added. The amount of research thus far carried out on the relationship between direct and indirect calorimetry has shown conclusively that an extensive series of observations can advantageously be made with such a respiration chamber without complicating the apparatus by delicate calorimetric features. A large respiration chamber has therefore been built by the Laboratory mechanicians in the respiration calorimeter laboratory. This chamber is 5.2 meters long, 3.8 meters wide, and 2.3 meters high, with a water-sealed opening at the top and large plate-glass windows at one end, permitting daylight illumination. In studies carried out with this apparatus, emphasis will be laid upon the determination of carbon dioxide developed under various conditions.

APPARATUS FOR THE MEASUREMENT OF LARGE AMOUNTS OF CARBON DIOXIDE.

The universal respiration apparatus is so adaptable that it has already been employed for researches varying as widely as the measurement of the gaseous metabolism of a single guinea-pig and of the carbon-dioxide production of a man working to the limit of human endurance. In this latter study the apparatus effectively absorbed from the ventilating air-current as much as 3 liters of carbon dioxide per minute. The quantity of chemical reagents required under such conditions to remove the carbon dioxide completely prohibits the use of this apparatus for experiments over long periods of time. Accordingly, in researches in which large amounts of carbon dioxide are to be absorbed, such as studies of the metabolism of large animals (particularly domestic animals), of a group of men, women, or children, or of one or two men working continuously at severe muscular labor, a very different type of respiration apparatus is required. Using as a basis a novel method for sampling a large air-current, we have devised an apparatus which gives excellent results in the measurement of considerable amounts of carbon dioxide. When the apparatus is attached to the large respiration chamber previously mentioned, it makes possible all types of experimentation with a number of individuals or under conditions of severe muscular work.

MINOR APPARATUS.

For the permanent retention of many of the unique processes developed in experimentation on man, it has been found advisable to take cinematograph records of the various techniques. Consequently, the Laboratory has been equipped with a suitable cinematograph camera and projection apparatus for this purpose. The films are of marked advantage in showing technique when, for one reason or another, apparatus has been dismantled.

An electrically-driven kymograph constructed by Schloer, of Bowie, Maryland, has also been added to the equipment of the Laboratory.

COOPERATING AND VISITING INVESTIGATORS.

Since the investigation in diabetes mellitus has become such a relatively important factor in the researches of the Nutrition Laboratory and a clinical respiration apparatus has been installed in the New England Deaconess Hospital, Professor Elliott P. Joslin, who has cooperated in this research for the past seven years, has devoted more than usual of his own time and that of his assistants to a continuation of the study. Dr. Joslin's activity in this field has recently been signalized by the publication of a treatise on diabetes mellitus, which summarizes in large measure many of the researches that have been carried out in this laboratory and gives his experience with some 1,000 cases.

Dr. Fritz B. Talbot, having made satisfactory arrangements with the Massachusetts Wet Nurse Directory, has taken charge of the researches on the metabolism of normal infants, *i. e.*, the children of healthy, inspected wet nurses.

Dr. George P. Denny, cooperating with Dr. F. M. Allen, of the Rockefeller Hospital, has contributed to the general research on diabetes by making observations on the gaseous metabolism of partially depancreatized dogs prior to and subsequent to sugar feeding. Dr. Denny's departure for the war zone in Europe has indefinitely postponed the completion of these observations.

Dr. J. Arthur Harris, of the Station for Experimental Evolution, Cold Spring Harbor, visited the Laboratory and was present at several conferences in New York City with regard to the statistical treatment of certain of the data thus far accumulated by the Laboratory. Dr. Harris's cooperation in the statistical handling of this material is taking an active form.

INVESTIGATIONS IN PROGRESS.

In accordance with the usual custom the investigations now actively in progress in this Laboratory are outlined herewith.

METABOLISM DURING MUSCULAR WORK.

The research on energy transformations during walking, which was begun by Doctors C. Tigerstedt and H. Murschhauser in 1913–14 on horizontal walking and continued by Dr. H. M. Smith in 1914–15 on grade walking, has been concluded, and the results of Dr. Smith's investigations are being tabulated. The Laboratory has been fortunate in having as subject a young man who has faithfully fulfilled the requirements of a hard forenoon's walk upgrade without breakfast. These observations were continued throughout the whole year, except for a brief period when the subject developed a tendon strain and it became necessary for him to be relieved for a short time. The results obtained with this subject are the most comprehensive of any secured thus far; when combined with those of the previous year they will, it is hoped,

furnish a complete picture of the total energy changes during this form of exercise.

The investigation has covered rates of progression from a very slow saunter of 35 meters per minute to a brisk pace of 100 meters per minute and from a zero grade to one of 45 per cent. At the higher grades it was, of course, impossible to maintain the greatest speeds. At the point of 40 per cent grade and 65 meters per minute speed, the subject consumed oxygen at the rate of 3,159 c. c. per minute, while 3,030 c. c. of carbon dioxide were eliminated. Electrocardiograms were taken at frequent intervals during the muscular activity. It has thus been possible to get authentic photographic records of the pulse during the muscular work, as well as of the changes during the transition from mild to vigorous exercise and the reverse. The Bock-Thoma oscillograph, used for this purpose last year, was replaced by a Cambridge string galvanometer, as the war made it impossible to secure certain broken parts of the former instrument. The records with the string galvanometer were equally satisfactory and the expense of photographic supplies was materially reduced

During the latter part of the investigation measurements were also made of the body-temperature by means of a rectal resistance-thermometer and a galvanometer; curves showing the changes in the body-temperature during work were thus simultaneously secured. Other data recorded during the study included the number of steps per minute, the height to which the body was lifted per minute, the respiration-rate, the volume per respiration, and the changes in blood-pressure. Throughout the entire investigation the treadmill, constructed in this Laboratory in 1912, gave excellent results. It is now being thoroughly examined and tested in preparation for use in the large respiration calorimeter.

METABOLISM IN RECTAL FEEDING WITH ALCOHOL AND SIMPLE SUGARS.

As a part of the research upon the physiological effect of ethyl alcohol in man, begun by this Laboratory, an extensive investigation of the use of alcohol in rectal feeding has been made by Dr. T. M. Carpenter. Four healthy medical students acted as subjects. Ethyl alcohol in concentrations of 5, 7.5, and 10 per cent in water has been injected per rectum in quantities varying from 250 c. c. to 1,000 c. c. of the diluted alcohol. In most of the tests 25 grams of the alcohol were used, although in some instances as much as 50 grams were given. The amount unabsorbed was determined by the so-called "wash out" method. The effect upon the character and amount of the total metabolism was found by determining the gaseous exchange with the Tissot respiration apparatus. By the application of a mask it was possible to measure the gaseous exchange continuously for 5 hours in periods of from 10 to 15 minutes. The total amount of air expired each period and its composition were determined. From these the total

carbon dioxide expired, the total oxygen absorbed, and the respiratory quotients were calculated. Simultaneously with the above measurements, continuous graphic records were obtained of the respiration-rate, pulse-rate, and external muscular activity. Control experiments of like character were made in which a 0.6 per cent sodium chloride solution was injected.

To throw additional light upon the absorption of alcohol per rectum, special experiments were also made in which the urine was collected in short periods and the alcohol concentration determined by the Nicloux method. For comparative purposes a few metabolism experiments of both kinds, *i. e.*, respiration experiments and those including the collection of urine, were conducted, in which the alcohol was administered through the mouth. A number of metabolism studies of rectal feeding were made by injecting 5 and 10 per cent solutions of dextrose and levulose in amounts up to 50 grams of these sugars; in two experiments alcohol and dextrose were combined. Incidentally, observations were carried out on the difference between the gaseous exchange with the subject awake and with the subject asleep.

The results obtained present many interesting facts and problems regarding both the physiological effect of alcohol and of rectal feeding in general. The investigation will be continued along both lines.

INFLUENCE OF MODERATE AMOUNTS OF ALCOHOL ON PSYCHOLOGICAL PROCESSES.

The observations previously made by Dr. W. R. Miles on the influence of alcohol on typewriting—a convenient and extensively used form of complex activity—produced a formidable mass of records which have been in process of elaboration during the year. These experiments were made with five trained typists who worked 5 hours per day for 6 to 10 days each. The other measurements with the typewriting, which might correspond to rest periods, bear mostly on the time relations of certain neuro-muscular processes. The typewriting provides a record not only of the speed of operation but also of the accuracy of the complex reactions involved. As the individual variations characteristic of the effects of alcohol are prominently shown, further experiments may have to be made before the results are reported.

SENSORY THRESHOLD FOR ELECTRICAL STIMULATION.

Certain practical difficulties have been found in the Martin method of measuring the sensory threshold for electrical stimulation, prominent among these being the care necessary for the accurate determination of the tissue resistance for the receptors involved. As this sensory threshold has been useful in studying the changes in the condition of the nervous system incident to the ingestion of moderate amounts of alcohol, and promises further usefulness, an effort has been made by

Dr. Miles to improve the technique. Work has been done along the following lines: A comparison of the wave forms and current strength of the different inductoria; the construction and calibration of a pendulum contact-breaker which can be used in the circuit of the induction coil to produce constant breaks or in work with direct-current stimulation; the employment of different forms of the Wheatstone bridge for measuring the tissue resistance. In the last-mentioned study both the telephone and the string galvanometer were used as detectors and determinations were obtained for resistance and capacity. The results secured were compared with the values found when the resistance was measured by the substitution method with the string galvanometer.

VISUAL ACUITY MEASUREMENT.

The Ives-Cobb visual acuity object has been used by Dr. Miles with a limited group of subjects for a thorough test of the relation between visual acuity and the diameter of the artificial pupil and of the luminous intensity of the field.

METABOLISM IN DIABETES MELLITUS.

The obscure respiratory problems presented by the peculiar condition of diabetic subjects subsequent to the new Allen fasting treatment called for an extended series of observations in the New England Deaconess Hospital under the general direction of Dr. Joslin. The observations were carried out by Miss M. A. Corson, of the Laboratory staff. The providing of a separate building for diabetics by the hospital has proved of great value, a visit to the building showing better than words the wide difference between these patients with severe diabetes and the ordinary conception of hospital patients. As Dr. Joslin has aptly pointed out, the diabetes patients are not in a hospital, but at school, learning how to prolong their own lives.

METABOLISM OF NORMAL INFANTS.

As the result of an excellent system of controls established by Dr. Talbot, we have been able to study a number of infants during the period of growth from birth to a year or more of age and to obtain an interesting series of charts showing the metabolism during the first two years of life. The apparatus installed in the Wet Nurse Directory has been used for daily observations on perfectly normal infants. In the spring of 1916 a series of observations was carried out in which an attempt was made to approximate the daily life of the infant in the crib and to determine the daily rhythm of metabolism, including the digestive cycles and the influence of deep sleep upon the metabolism. The periods were 24 hours long, the infant being removed from the respiration chamber but a few moments at a time throughout the entire day. These tedious and exacting observations have been in charge of Miss Alice Johnson.

INFLUENCE OF ENVIRONMENTAL TEMPERATURE ON METABOLISM.

By means of the clinical respiration chamber a study has been begun of the carbon-dioxide production and oxygen consumption of a human subject under conditions of varying environmental temperature—a factor which is popularly supposed to affect profoundly the basal metabolism. Similarly with smaller forms of respiration chambers the same temperature conditions have been applied to small animals, such as dogs, cats, and, particularly, geese and ducks.

THE CONVERSION OF CARBOHYDRATES TO FAT IN THE ANIMAL BODY.

The double problem of the conversion of carbohydrate to fat, such as occurs during surfeit feeding of geese and obesity in man, and the interesting energy relationships between the carbon dioxide formed and the oxygen consumed during these processes, can be simultaneously studied with great profit by using geese as subjects and determining the gaseous metabolism and heat production with the recently completed respiration calorimeter for small animals. Such an investigation has been begun and considerable progress has been made with the experimental attention of Miss E. H. Tompkins and Miss Alice Johnson.

THE METABOLISM OF COLD-BLOODED ANIMALS.

As stated in earlier reports, a most advantageous arrangement has been made for research at the New York Zoological Park, by means of which valuable data may be obtained for comparative purposes on the basal metabolism of the lower animals. With the assistance of Mr. Colbert Mason, an excellent beginning has been made on an extensive study of the metabolism of cold-blooded animals, particularly serpents and tortoises. Owing to Mr. Mason's ill health, we are so unfortunate as to lose his services, but the research is being actively continued with the assistance of Mr. E. L. Fox. Publication of the results will not be possible until the data accumulated are much more extensive.

EDITORIAL AND COMPUTING WORK.

The preparation of the large monographs describing the technique and protocols and discussing the results of the investigations carried out in this Laboratory have necessitated a special division of computing and editing that is completely equipped with modern computing devices. Several scientific contributions in the form of either journal articles or of monographs are constantly in hand. Reference should also be made to the investigation on the applicability of modern statistical treatment to the vast amount of data which is being gathered together. As a result of several conferences with biological statisticians, notably Dr. C. B. Davenport, Dr. Raymond Pearl, and Dr. J. Arthur Harris, arrangements have been made with Dr. Harris to apply statistical treatment to several characteristic sets of the data which have already been accumulated.

TRANSLATION OF FOREIGN LITERATURE.

Following the practice of other years, the Laboratory has continued the translation of scientific treatises not readily accessible to the research worker. The translations from the Russian made during the past year are as follows:

A. A. Studenski:
Comparison of heat-production (calculated and directly determined) of dogs in normal condition, in fever, and in pregnancy. From the Laboratory of General Pathology of Professor Albitsky. Dissertation, St. Petersburg, 1897, 57 pp.

M. M. Kulagin:
Life without oxygen. Jour. Nat. Sci. and Geog., 1906, 3, 11 pp.

J. A. Kagan:
Influence of fasting on the increase in body-weight upon renewed feeding with limited amounts of food. Jour. Russian Med., 1885, Nos. 17, 18, and 19, 21 pp.

PUBLICATIONS.

The following publications have been issued during the year:

(1) Energy transformations during horizontal walking. Francis G. Benedict and Hans Murschhauser. Proc. Nat. Acad. Sci., 1, 597 (1915).

An abbreviated presentation of the material in Publication No. 231, Carnegie Institution of Washington (1915).

(2) The physiology of the new-born infant. Francis G. Benedict and Fritz B. Talbot. Proc. Nat. Acad. Sci., 1, 600 (1915).

An abbreviated presentation of the material in Publication No. 233, Carnegie Institution of Washington (1915).

(3) A comparison of methods for determining the respiratory exchange of man. Thorne M. Carpenter. Proc. Nat. Acad. Sci., 1, 602 (1915).

An abbreviated presentation of the material in Publication No. 216, Carnegie Institution of Washington (1915).

(4) Neuro-muscular effects of moderate doses of alcohol. Raymond Dodge and Francis G. Benedict. Proc. Nat. Acad. Sci., 1, 605 (1915).

An abbreviated presentation of the material in Publication No. 232, Carnegie Institution of Washington (1915).

(5) The pathological effects of atmospheres rich in oxygen. Howard T. Karsner. Journ. Exp. Med., 23, 149 (1916).

It has been known for many years that pneumonia is produced by the more or less prolonged inhalation of high partial pressures of oxygen. The studies herein reported show that atmospheres containing 80 to 96 per cent oxygen under normal barometric pressure produce in 24 hours, or more commonly 48 hours, congestion, edema, epithelial degeneration and desquamation, fibrin formation, and finally, a pneumonia, probably of irritative origin and to be described as a fibrinous bronchopneumonia. The important new points are the time relations of these changes and definition of the type of the pneumonia. Other studies have noted slight passive congestion, but it is now established that this is to be accounted for in most cases by dilatation of the right side or of both sides of the heart. This congestion affects all the abdominal viscera and is accompanied by certain secondary changes such as cloudy swelling of the parenchymatous organs and phagocytosis of erythro-

cytes by endothelial cells of the mesenteric lymph nodes. Although deficiency of oxygen may affect the hematopoietic system, the animals subjected to high oxygen percentages failed to show demonstrable pathologic changes in blood, spleen, lymph nodes, or bone marrow, except for the presence of congestion.

(6) **A study of acidosis in three normal subjects, with incidental observations on the action of alcohol as an antiketogenic agent. H. L. Higgins, F. W. Peabody, and R. Fitz. Journ. Med. Research, 34, 263 (1916).**

In three healthy subjects a carbohydrate-free diet caused the development of varying degrees of acidosis. The acidosis was shown by a lowered CO_2 tension of the alveolar air, by an increased urinary excretion of ammonia nitrogen and of acetone bodies, and by the increased titratable acidity of the urine. The acidosis was accompanied by subjective sensations of malaise, an increased oxygen consumption, a negative nitrogen balance, increased pulse-rate and increased ventilation. Alcohol given to the subjects on this diet in dosage comparable to that used for clinical purposes did not stop the progress of the acidosis or show any antiketogenic action. Coincidental with its administration there was further increase in the oxygen consumption and in the disagreeable subjective symptoms.

(7) **The alcohol program of the Nutrition Laboratory, with special reference to psychological effects of moderate doses of alcohol on man. Francis G. Benedict. Science, 43, 907 (1916).**

The preparation of a program outlining the more fundamental problems for study in an investigation of the physiological and psychological effects of moderate doses of alcohol on man led to an extensive correspondence and personal discussion with regard to the plan in general. The plan is outlined in this address, and special reference is given to a presentation of some of the more fundamental conclusions drawn from the monograph of Dodge and Benedict (Publication No. 232, Carnegie Institution of Washington (1915).

(8) **Respiratory exchange, with a description of a respiration apparatus for clinical use. Francis G. Benedict and Edna H. Tompkins. Boston Med. and Surg. Jour., 174, pp. 857, 898, 939 (1916)**

The interest of the medical profession in respiratory exchange led to the preparation of this discussion of the theory of the respiratory exchange and its significance in pathology, together with the presentation of the description of a special apparatus for clinical use. This apparatus has been tested and extensively used in the New England Deaconess Hospital in the long series of researches on diabetes. The technique of the operation of the apparatus for experiments with diabetic patients is given in detail.

(9) **The rapidity with which alcohol and some sugars may serve as nutriment. Harold L. Higgins. Am. Jour. Physiol., 41, 258 (1916).**

By determination of respiratory quotients in periods of 3 and 4 minutes' duration upon subjects without breakfast, it was concluded that: Alcohol begins to be burned in appreciable quantity in from 5 to 11 minutes after taking; with some subjects the combustion began more quickly than with others. Sucrose, lactose, and levulose begin to be burned quite as soon as alcohol, if not sooner. Glucose and maltose are not utilized as food as soon as the other sugars or alcohol, approximately 20 to 30 minutes elapsing before their combustion plays an important part in the metabolism. There is a distinct difference between the metabolism in man of glucose and of levulose and galactose, as shown by a study of the gaseous exchange, especially of the respiratory quotients.

(10) **A photographic method for measuring the surface area of the human body. Francis G. Benedict. Am. Jour. Physiol., 41, 275 (1916).**

Primarily with the object of securing measurements for a subject who had undergone a 31-day fast, a photographic method was developed to establish the relationship between the area of the body computed from certain definite photographic poses (particularly a side view with arm extended) and that actually measured by the Du Bois linear formula. A method for securing accurate measurements of the body area resulted. Comparisons between the photographed areas and the body-surface as computed from the Du Bois linear formula show, even with the most diverse configurations of body, a constancy rarely observed in anatomical measurements or in computed ratios based upon such measurements.

(11) The relationship between body-surface and heat-production, especially during prolonged fasting. Francis G. Benedict. Am. Jour. Physiol., 41, 292 (1916).

An historical consideration of the development of the idea of proportionality between the body-surface area and heat-production shows that fundamentally it was originally based upon Newton's law of cooling. The idea of a causal relationship between body-surface and heat-production is strongly emphasized in foreign writings and distinctly to be inferred from those of a number of American writers. The long-existing doubts as to the validity of the older methods for the measurement of body-surface have been fully substantiated by the development of the linear formula of the Du Boises, which gives measurements with a high degree of accuracy.

By means of a photographic method recently devised for measuring the body-surface, the body-area of the subject of a 31-day fasting experiment was redetermined and used in recomputing the heat-production per square meter of body-surface. The values obtained showed a decrease similar to that previously found. The decrease in the heat-production per square meter of body-surface, amounted to 28 per cent, a decrease that can be interpreted only as proof of the inapplicability of the surface-area law to subjects with widely varying states of nutrition. This shows it to be impossible to compare a standard value obtained with a large number of robust, normal individuals with that obtained with emaciated diabetics, and thus supplies strong proof of the legitimacy and practicability of the group system of comparing pathological cases with normal individuals of like height and weight, *i. e.*, of general anatomical and morphological similarity.

(12) The energy metabolism of a cretin. Fritz B. Talbot. Am. Jour. Diseases of Children, 12, 145 (1916).

This brief study of the metabolism of a cretin is of significance, since it gives evidence as to the influence of the internal secretion upon the metabolism. The cretin was 3 years' and 8 months old, weighed 12 kg., and had the mental development of a 4 to 6 months' old infant. After treatment with thyroid extract he improved markedly, showed more intelligence, and became more active. Before treatment two very quiet periods were obtained with him, but, unfortunately from the standpoint of observation, after treatment he showed signs of discomfort in the restricted space of the chamber and it was impossible to secure comparable quiet periods. His metabolism in the quiet periods is compared with that of two normal infants 8½ and 10 months old, respectively, the observations showing that, in general, the metabolism of the cretin was 25 per cent lower than that of the two normal infants.

DEPARTMENT OF TERRESTRIAL MAGNETISM.*

L. A. BAUER, DIRECTOR.

GENERAL SUMMARY.

The event of chief importance in the publication work of the Department is the completion of Volume III of its Researches. This volume contains the final results of the ocean magnetic work, 1905–1914, and the preliminary results for the present cruise of the *Carnegie*, from March 1915 to September 1916; also, accounts are given of various investigations, especially with regard to observational methods and newly designed instruments for the ocean work.

The three cruises of the *Galilee*, 1905–1908, aggregated 63,834 nautical miles, and the four cruises of the *Carnegie*, 1909 to 1916 (September), 160,615 nautical miles. The aggregate length of the cruises of the two vessels, 1905 to 1916 (September), is, accordingly, 224,449 nautical miles. On the average, magnetic observations at sea have now been made at points 100 to 150 miles apart, and the results will be found in the "Tables of Results" given in Volume III. The various tables contain the results for 443 stations of the *Galilee* work and for 2,807 stations (to September 21, 1916) of the *Carnegie* work; hence, together, for 3,250 stations to September 21, 1916. In addition, magnetic observations have been made at numerous shore stations.

The great advantage of having a non-magnetic ship, like the *Carnegie*, is made very apparent in the comparison of the work of the *Galilee* and the *Carnegie*, both as to accuracy and rapidity of work. While the operating expenses of the chartered vessel, the *Galilee*, were less than those of the *Carnegie*, the difference was more than made up by the fewer results during a given period and the increased cost of the office work for the *Galilee*, because of the need of determining deviation corrections, which is not necessary for the *Carnegie*.

The general plan according to which the magnetic survey of the globe is being carried out provides not only for securing magnetic data in all regions where needed, but also for the determination of the average annual changes, the so-called "secular changes" in the Earth's magnetic state. On the oceans this is done by making observations at intersections with previous cruises of the *Galilee* and the *Carnegie*, or with the tracks followed by the vessels used in recent Antarctic expeditions. Up to October 1, 1916, such repeat observations have been made at about 85 intersections of cruises of the *Galilee* and the *Carnegie*, the average time-interval being approximately 5 years. In addition, the secular changes have been determined by the observers at many points on land (islands and continents).

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The magnetic data accumulated by the end of 1917 will warrant undertaking then the reduction of all results to some common date by applying the secular changes just mentioned. When this has been done a new set of magnetic charts for the globe can be constructed on a more accurate basis than has been possible heretofore. It is hoped that the solution of some of the vexed and mooted questions pertaining to the magnetism of our planet may then be undertaken successfully.

Volume III, which shortly will be ready for distribution, contains also a special report on the results of the atmospheric-electric observations made at sea on the *Galilee* and the *Carnegie* during the periods 1907–1908, and 1909–1916. By referring to the abstract on pages 326 to 329, it will be seen that results of importance have been obtained also in this line of work. The improved methods and instruments in use on the *Carnegie* since 1915 promise to yield further important facts.

Magnetic data of interest to mariners have been mailed to the chief hydrographic establishments with the same promptness as heretofore. Owing to interrupted mail service in European countries, however, the receipt of the data is at times delayed. With the publication of Volume III, hydrographic establishments are put in possession of the complete ocean magnetic results to September 1916.

MAGNETIC SURVEY OF THE OCEANS.

At the close of the last fiscal year the *Carnegie* was en route from Dutch Harbor, Alaska, to Lyttelton, New Zealand, where she arrived, after a continuous trip of 89 days, on November 3, 1915. After the completion of the usual shore work and the instrumental comparisons at Christchurch Magnetic Observatory, she sailed from Lyttelton December 6 on a most memorable voyage—the circumnavigation of the sub-Antarctic regions. Proceeding eastward for the greater part near the parallel of about 60° south, she arrived at King Edward Cove, South Georgia Island, in the South Atlantic, on January 12, 1916. Leaving this port two days later, the *Carnegie* continued eastward and returned to Lyttelton on April 1, 1916, having accomplished the circumnavigation passage of 17,084 nautical miles in 118 days, the average day's run under sail being 145 miles.

As far as is known, the *Carnegie* is the first vessel to make the circumnavigation of the globe in the sub-Antarctic regions complete in one season. On every day of the entire passage full sets of magnetic observations were made, excepting on one day, when, because of cloudiness, the value of the magnetic declination (variation of the compass) could not be determined; however, on this day the magnetic inclination and the intensity of the Earth's magnetic field were observed. Off the southwest coast of Australia, mariners' charts of the variation of the compass were found in error 12° to 16°, the largest errors thus far revealed. Besides important magnetic and electric data, information

of geographic interest was obtained on this trip. The probable non-existence of Dougherty Island was confirmed and the geographic position of Lindsay Island, as determined by the German exploring ship, the *Valdivia*, in 1898, was verified. The interested reader may be referred to the fuller account of the trip on pages 297 to 301.

The *Carnegie* left Lyttelton again on May 17, 1916, bound for Pago Pago, Samoa, arriving there June 7. Sailing from this port on June 19, she proceeded next to Guam in order to connect there with the 1907 work of the *Galilee*. The *Carnegie* was at Port Apra, Guam, from July 17 to August 6, during which period important shore observations and instrumental comparisons were made. Leaving Guam August 6, the vessel followed a track to San Francisco designed to secure as many intersections as possible with the previous tracks of the *Galilee* and the *Carnegie*, and to obtain magnetic observations in areas where additional data are needed. The *Carnegie* arrived at San Francisco September 21, 1916. Here connection was made with the work of the *Galilee* 1905–1908. After again outfitting, the vessel on November 1 started on her homeward trip around the Horn and via certain Atlantic ports to Brooklyn, where she is expected in the fall of 1917. The total length of the *Carnegie's* passages during the period November 1, 1915, to October 31, 1916, is 29,856 nautical miles.

When the *Carnegie* returns to Brooklyn, magnetic data will have been secured in nearly all the oceans traversed—in brief, the first general magnetic survey of the oceans will have been nearly completed. The Arctic and Antarctic regions, not accessible to the *Carnegie* because she is not built for severe ice-conditions, must be covered in some other manner. But much useful work remains for the *Carnegie*. In the first place, it will be necessary to repeat magnetic observations at intersections of the tracks of previous cruises in order to ascertain the changes in the magnetic elements, so that mariners' magnetic charts may always be kept up to date, and to provide the requisite data for the scientific study of the causes of these changes. Beginning with 1918, however, except in certain regions, it will be possible to reduce the average daily routine of magnetic work and to devote the time gained thereby to acquiring data in various other important lines of oceanographic work and scientific inquiry. Indeed, had the *Carnegie* no other useful mission, it would be a profitable investment to reserve her solely for the determination of the annual changes in the Earth's magnetic state. Frequently the errors found in the mariners' charts are attributable largely to erroneous amounts of annual changes which the constructors of the charts, in the absence of accurate information, adopted in order to refer past magnetic data to a future date.

But it is not merely the practical importance of magnetic data concerning the Earth's magnetic changes that is here had in mind. The acquirement of the scientific data necessary for the ultimate ascer-

tainment of the causes of the changes in the Earth's magnetism, which in a comparatively few years suffice to produce noticeable alterations and to vitiate the utility of mariners' charts, if not corrected, is believed by many to be of the highest importance in our studies of the past and future history of the Earth. The value of accurate magnetic data can probably not be fully estimated at present, but will increase with lapse of time.

MAGNETIC SURVEY OF LAND AREAS.

Naturally the war has interfered with the steady progress of the magnetic surveys of certain regions under the jurisdiction of European countries. The work accomplished during the period November 1, 1915, to October 31, 1916, may be summarized as follows:

1. Extensive trips in Northern China, Mongolia, and Manchuria, under the direction of Dr. C. K. Edmunds, assisted by Observer F. Brown.
2. Trips by Observer W. C. Parkinson to British New Guinea and outlying islands of Australasia, and in the interior of New Zealand and Australia. (See also observations under Magnetic Observatory Work.)
3. Interior trips by Observer H. E. Sawyer in French Kongo and Belgian Kongo, as also magnetic observations at some stations en route from Durban, Africa, to Boma, Belgian Kongo.
4. Magnetic observations at 13 stations on the island of Tahiti and in California by Observer H. F. Johnston.
5. Magnetic observations by Observers D. M. Wise and A. Sterling in the northwestern part of South America.

MAGNETIC OBSERVATORY WORK.

Upon the completion of Observer Parkinson's work in New Zealand in May 1916, he was assigned to Southwestern Australia to examine sites for one of the proposed magnetic observatories mentioned in the report of last year. In connection with these examinations, magnetic observations were made at various stations. In the meanwhile the building plans for the observatory were prepared at Washington by the Chief of the Observatory Division, Mr. J. A. Fleming, who was assisted by Magnetician W. F. Wallis. The latter left Washington for Australia in July 1916 to take charge of the erection of the observatory buildings and the installation and operation of the instruments. The site chosen is located near Marchagee, about 150 miles north of Perth, Australia. Mr. Wallis is being assisted in the work by Mr. Parkinson.

In September 1916, Observer D. M. Wise left Washington for South America to instruct Observer A. Sterling in magnetic-survey work, and especially to examine into the suitability of localities in Peru for a second magnetic observatory, to be established, if possible, in 1917.

RESEARCH WORK IN WASHINGTON.

TERRESTRIAL MAGNETISM.

Volume III of Publication No. 175, bearing the title "Ocean Magnetic Observations, 1905 to 1916, and Reports on Special Researches, by L. A. Bauer, W. J. Peters, J. A. Fleming, J. P. Ault and W. F. G. Swann," already spoken of in the introductory paragraphs of this report, is in the hands of the printer at the end of the fiscal year. Abstracts concerning this volume will be found on pages 326–329. Progress has been made with Volume IV (Magnetic Survey Observations, 1914–1917, and Reports on Special Researches). This volume is to contain both the land and ocean results for the years specified.

In addition to the publication work and the completion of the investigations contained in Volume III, various investigations, theoretical and observational, have been carried on, the majority of which are described in the abstracts of papers (pages 318–336). The investigations relating to instrumental improvements, to the designing of new appliances, and to the laws governing changes of constants of magnetic instruments, have been continued (see page 294). The results of some of these investigations are to appear in Volume IV.

The Director has continued his researches respecting the origin of the Earth's magnetic field, the relation between changes in solar activity and the Earth's magnetic activity, and as to the existence of a possible connection between outstanding astronomical effects and certain cosmic magnetic phenomena. The last question is engaging the attention at present of several noted investigators (see page 321), and it is becoming increasingly difficult to draw a sharp boundary-line between researches belonging distinctively to one or the other of the older sciences. Thus the student of the Earth's magnetism soon finds that he must extend his investigations beyond our planet and take into consideration the existence of cosmic effects of various kinds.

As one of the first steps, it was considered desirable to attempt the establishment of a theoretical formula which would give an approximate idea, at least, of the possible magnetic field-strength of the main members of our solar system, assuming that the magnetic field of a large body is associated in some manner with speed and direction of rotation. On page 321 a tentative formula is given. If we take as the period of the Sun's rotation that derived from the equatorial motion of sun-spots, etc., the formula gives as the strength of the Sun's magnetic field at its magnetic poles 114 times that of the Earth at its magnetic poles. Taking the Sun's rotation period as derived from the Mount Wilson observations, from which the motion of the Sun's magnetic axis about the rotation axis can be deduced, the strength of the Sun's magnetic field, according to the formula, turns out to be 90 times that of the Earth. Hale has deduced from his

preliminary observations that the strength of the Sun's general magnetic field at its magnetic poles is approximately 80 times that of the Earth at its magnetic poles. It is thus seen that the tentative formula agrees with observation as closely as could be expected in view of the uncertainty in the period of the Sun's rotation as a whole. Furthermore, Hale thinks it possible that his preliminary value may be increased if the Zeeman effect for spectrum lines representing lower levels in the solar atmosphere can be observed.

Unfortunately, it is not possible at present to test the formula further, since we do not know the magnetic field-strength of any other member of the solar system than the Earth and the Sun. It is of interest to note, however, that if the formula should receive further verification, it would appear probable that Jupiter may be enveloped by as strong a magnetic field as the Sun, and that Saturn, Uranus, and Neptune may have magnetic fields considerably stronger than that of the Earth. The possibility of decisive laboratory experiments is receiving further attention.

For additional information regarding above researches, see abstracts on pages 318 330.

It is appropriate to mention here the loss sustained by terrestrial magnetism in the death of Sir Arthur Rucker on November 3, 1915, in his sixty-seventh year. He was a member of the advisory council of the Department of Terrestrial Magnetism from the time of its establishment in 1904. He continued his kindly and stimulating interest practically until the day of his death. His counsel was found exceedingly helpful in determining on the final policy for the conduct of the world-wide work of the Department. In October 1909 he visited the *Carnegie* at Falmouth, England, and wrote an appreciative letter to the President of the Institution respecting the instruments and methods of work used on the vessel. He also wrote a report entitled "Observations on the magnetic results obtained at and near Falmouth Observatory by the *Carnegie* Expedition, October 1909." In this report a comparison is made between the magnetic results derived from the Rucker and Thorpe Magnetic Survey of Great Britain and those of the *Carnegie* expedition. He concluded his report as follows:

"The agreement of British and *Carnegie* measurements with each other, whether taken on sea or land, is all that could be desired, even when tested by methods in which small errors would be at once detected. The net result is to show that two surveys of countries 3,000 miles apart can be connected with each other with almost perfect accuracy, and that sea observations can, in the single case investigated, be linked up with land observations so as to secure an agreement in the general indications afforded even by the differences of the differences between the observed and calculated values of the magnetic elements."

TERRESTRIAL ELECTRICITY.

The investigational work under this head during the past year has been in the subjects of atmospheric electricity and earth-currents. The first special report of Volume III, referred to above, by L. A. Bauer and W. F. G. Swann, concerns itself with the compilation and discussion of the atmospheric-electric observations made on the *Galilee*, 1907–1908, and on the *Carnegie*, 1909–1916. (For abstract, see pages 326–329.)

Progress has been made by Doctors W. F. G. Swann and S. J. Mauchly with newly designed instruments for automatic registration of the atmospheric-electric elements, to be used at Washington and at the observatories of the Department. It is hoped that the automatic registration of the potential gradient and the electric conductivity of the atmosphere with the new instruments can be begun at Washington by the end of 1916. Abstracts of various related investigations are to be found on pages 331-336.

The great advantage of being able to combine laboratory investigations with observational work is again being demonstrated, this time in the subject relating to the Earth's electric currents. It is the intention to include in the work of the Department's proposed observatories the automatic registration of earth-currents. However, in view of the conflicting results obtained by past observers, it has been decided to undertake first some theoretical and experimental studies at Washington. The problem has been assigned to Doctors Swann and Mauchly.

The first point under investigation concerns itself with the origin of vertical earth-currents. It appears that many investigators have observed vertical earth-current densities of an order of magnitude much larger than the vertical atmospheric-electric current density. The existence of a general distribution of such vertical earth-currents appeared inconsistent with the principle of continuity of electric flow. Laboratory experiments show that the currents can largely be attributed, both as regards their nature and order of magnitude, to spurious effects introduced by the apparatus through differential effects of such agencies as temperature or hydrostatic pressure, for example, at the electrodes. The investigation is now being continued in the grounds around the Laboratory.

Further studies and experiments have been made in connection with the atmospheric-electric work of the *Carnegie*. Dr. Swann also has in progress various investigations regarding the maintenance of the Earth's electric charge and related topics. (See abstracts of papers, pages 331–336.)

INSTRUMENTAL WORK.

Besides the instrumental investigations already mentioned (see pages 291, and 317-318), several new instruments for observations in terrestrial magnetism and atmospheric electricity have been completed in the Department's instrument-shop, which has continued, as heretofore, under Mr. Fleming's supervision. Furthermore, the current instrumental equipment has been kept in good repair and the magnetic instruments for observatory work, purchased from the United States Government and formerly used at Mount Weather Observatory, have been thoroughly overhauled, improved, and in part reconstructed. The Department now has three complete magnetograph outfits.

The reconstructed magnetic instruments were originally made by some of the best foreign instrument-makers. Despite the splendid workmanship, it was found necessary when overhauling the instruments to replace, because of magnetic impurities, a number of the parts. The great importance of securing absolutely non-magnetic metals for magnetic instruments, pointed out in previous annual reports, was thus again emphasized. A small brass-foundry, to insure the making of pure castings, was therefore constructed and equipped and the necessary arrangements were made for refining the raw metals required.

During the year two of the Department's types of magnetometers have been purchased by foreign governments.

It is of interest to record here that the Board of Directors of the University of Cincinnati presented to the Department, for its historical exhibit of magnetic instruments, the large Gambey type of magnetometer used by Professor Alexander Dallas Bache when making the magnetic survey of Pennsylvania, 1840-1843.

Additional experimental direct-current circuits and special bare-wire circuits with special switchboards for the laboratory rooms were completed, and various instrument-cabinets and observing-tables were installed.

Test runs and adjustments of two of the magnetograph outfits were completed at Washington preparatory to the assignment of the instruments for use at the proposed observatories in Western Australia and South America. Both outfits are of the Eschenhagen type.

DETAILS OF OBSERVATIONAL WORK.

OCEAN WORK.

November 3, 1915, the *Carnegie* arrived at Lyttelton, New Zealand, and thus concluded her long trip, without stop, of 89 days from Dutch Harbor, Alaska, from which port she had sailed on August 5. Heavy weather was encountered immediately after leaving Dutch Harbor,

and it was impossible to swing ship[1] until August 15, just before leaving Bering Sea. The farthest north was 59° 33′.

The one hundred and eightieth meridian was crossed on August 13, the date August 14, 1915, being dropped. After clearing the Aleutian Islands, the course followed was practically south along the one hundred and sixty-fifth meridian to New Zealand. On September 6 a terrific gale and hurricane from the southwest was encountered. It was necessary to take in all sail and run before the storm, and for 17 hours a speed of 9 knots was made under bare poles. The vessel stood the strain well, but everything was wet on board, the hurricane driving the rain into every crack and opening. Wake Island was passed in the morning of September 12. After passing the first of the Marshall Islands, it was deemed best to keep pretty well to the east on account of prevailing easterly winds and westerly set of the currents. It was necessary to pass well to the westward of the Santa Cruz-Solomon Islands passage, while near the equator, but favorable conditions made it possible to weather the Solomon Islands, the engine operating during calms.

After passing the Solomon Islands, the *Carnegie* was driven to the westward by the prevailing southeast winds and had to tack twice to avoid the Indispensable Reefs. These reefs were passed October 12, and all the islands and reefs in the Coral Sea were safely cleared. As the Coral Sea was entered, the winds drew somewhat more to the southward, making it necessary to near the Australian Coast off Brisbane. Good winds were blowing across the Tasman Sea, and the light on South Island, New Zealand, east entrance to Foveaux Strait, was made early in the morning of October 31. On account of the slow trip, it was decided to pass through the strait; just before clearing the east end of the strait at sunset the wind shifted to the southeast, making it necessary to use the auxiliary power. Fortunately, the engine was in good condition and enough coal was reserved for such an emergency. Again, in trying to round Banks Peninsula to enter Port Lyttelton, the wind shifted ahead. With the engine and fore-and-aft sails, however, it was possible to tack to advantage against the wind, thus saving a delay of a day or more in entering the harbor at Lyttelton. The engine has proved its value on several occasions and has run well. Only once during the trip did it fail to operate, and the cause for this failure was definitely placed.

During the cruise, various and unusual currents were noted. The winds encountered were light and baffling; very rarely were the yards braced square for a fair wind. The total number of miles on the passage was 8,865, an average of 100 miles per day for 89 days.

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[1]The purpose of occasionally making magnetic observations while swinging ship is to test, from time to time, the absence, for the *Carnegie*, of deviation-corrections large enough to be taken into account.

Local magnetic disturbances were noted on September 18 near Marshall Islands; October 15, west of Chesterfield Reefs and Islets; October 20 and 21, near the coast of Australia; and October 31, 1915, in Foveaux Strait. The aurora australis was seen on the nights of November 1 and 2, consisting of long beams of white light projected vertically from the southern half of the horizon.

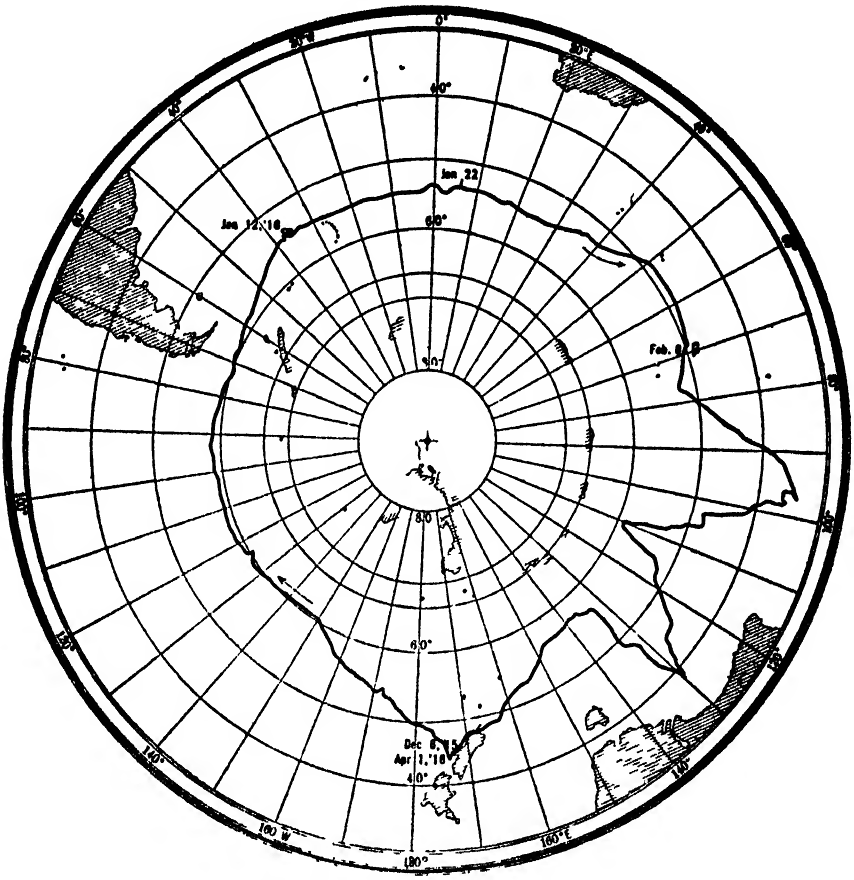


FIG. 2.—The track followed by the *Carnegie* on her sub-Antarctic voyage, December 6, 1915, to April 1, 1916.

Lyttelton was reached with over 6 tons of coal remaining in the bunkers, 40 gallons of kerosene, and 600 gallons of water. It was not necessary to issue a restricted quantity of water per day to each man, as all did their best to economize in the use of fresh water. A salt-water shower-bath, connected with the deck pump, was in position ready for use at all times. The health of the party was good during the entire trip.

A stay of 33 days at Lyttelton was necessary for the completion of the shore-work and instrumental comparisons at Christchurch Magnetic Observatory, and for the overhauling and outfitting of the vessel. On December 6 the *Carnegie* left Lyttelton for a circumnavigation of the sub-Antarctic regions. The one hundred and eightieth meridian

was crossed on December 9, so that date was repeated as December 9 (2). The vessel arrived at King Edward Cove, South Georgia, on January 12, 1916, going the last 24 hours under her own auxiliary power. The *Carnegie* again sailed on the 14th, being towed out of harbor against a heavy head-wind by the steam whaler *Fortuna.* Icebergs became more numerous, and fog was almost continuous. However, January 18, 1916, was the only day on the entire trip in southern waters on which it was impossible to obtain observations for the magnetic declination. On January 22 the vessel passed along the north coast of Lindsay Island, about 3 miles off shore. The *Carnegie's* track of 1911 to the westward of Australia was twice intersected for the determination of secular changes. Lyttelton was reached on April 1, 1916. This sub-Antarctic passage was made practically between the parallels of 50° and 60° south until Australia was approached, when it became necessary, on two occasions, to cross somewhat north of the fiftieth parallel, in order to secure the intersections just mentioned. The total distance run from Lyttelton to Lyttelton was 17,084 miles, giving an average of 145 miles for 118 days. The entire track followed is shown in figure 2.

The following extracts from the commander's reports on the circumnavigation voyage are of interest:

"For the first week after leaving Lyttelton the winds were mainly from the SSW., forcing us considerably to the eastward of our route; so much so that we sighted the Antipodes, bearing south, distant 20 miles, on December 9, and would have passed over the charted position of the Nimrod Group had the wind remained in the south another 12 hours. It had not been the intention to go near this group, but the adverse winds sending us so near them, it was decided to stand on toward the east another day, to endeavor to sight them, but the wind shifted to the north 12 hours too soon and we passed 40 miles to the SW. of the position. [The Nimrod Islands were stated to have been seen, at a considerable distance, by Capt. Henry Eilbech in the *Nimrod* in 1828, who placed them in about 56½° S. and 158½° W.[1]]

"On December 7, a mirage presenting the appearance of distinct and extensive land was seen in the west, in the direction of Banks Peninsula, which was 190 miles distant at the time.

"We crossed the one hundred and eightieth meridian December 9, so repeated the date as December 9 (2). Our first piece of ice was sighted on December 18, lat. 60° 12′ S., long. 150° 46′ W., and on December 19, 30 icebergs, some being over 400 feet high and 1 mile long, were passed. We had snow on December 18, 19, 20, and 21, and rather wintry weather. The barometer dropped to 28.26 inches on December 18 during the snowstorm. No icebergs were seen after December 24 until January 10, just before arrival at South Georgia, when 8 or 10 good-sized bergs were passed.

[1]According to *Nature*, vol. 97, No. 2431, June 1, 1916, p. 237, "In 1909, on the homeward voyage of the *Nimrod*, with Sir E. H. Shackleton's Antarctic Expedition, Capt. J. K. Davis made a thorough search for the Nimrod and Dougherty Islands, and failed to find them; they were in consequence removed from the last edition of the Prince of Monaco's bathymetrical chart of the oceans."

"As our route lay near the charted position of Dougherty Island, we determined to look for it. On the afternoon of December 24, the cry of 'land ahead' was given and we saw what appeared to be a bold, dark rock-island. Immediately our course was shaped to pass near it. Everyone was convinced that either a new island had been discovered or that the position given for Dougherty Island was very much in error. It seemed to be a rocky cliff with a snow cap. Nearer approach, however, proved that the supposed island was an iceberg, 225 feet high by one-fourth mile long. The light was reflected from the perpendicular ice-wall in such a way as to give to the berg the appearance of a huge dark rock. The morning of December 25 found us within 3 miles of the position given for Dougherty Island. The weather was cloudy, but the seeing was good. Nothing could be seen from the masthead. I went aloft myself every half hour while we were passing the position given for the island. Had anything over 100 feet high been within 35 miles of the vessel in any direction we would have seen it. At $3^h 40^m$ a. m., December 25, Dougherty Island should have been 3 miles SE. of us. There was nothing visible within a radius of 35 miles at the time. The island has either been charted in the wrong place or it has disappeared, or possibly it was an ice-island. Our experience on December 24 would confirm the possibilities of optical illusions. The *Carnegie's* track (see fig. 2) extended from lat. 59° 28′ S., long. 123° 17′ W., to lat. 59° 08′ S., long. 110° 10′ W.; daylight and good seeing were had all the time. If anyone else attempts to locate the island, he should try either 40 miles south or 40 miles north of the charted position. We assumed the island to be at 59° 21′ S., and between 119° 10′ W. to 120° 20′ W. [Dougherty Island was supposed to have been seen by Capt. Dougherty in the *James Stewart* in 1841, who located it approximately in latitude 59° 20′ S. and longitude 120° 20′ W. In 1859 Capt. E. Keates in the *Louise* sighted an island, assumed to be Dougherty, assigning the position to it: 59° 21′ S. and 119° 07′ W.[1]]

"December 30 and 31 were the first fine days experienced since our departure from Lyttelton. In spite of storms, rain, snow, fog, and prevailing cloudy weather, we succeeded in getting declination observations daily, and averaging twice daily during the entire trip. This was accomplished by taking advantage of every opportunity and spending considerable time standing by. Frequently we would make six or more trips to the bridge before being successful. At other times observations would be made during the only 5 or 10 minutes that the Sun was visible on the entire day.

"The winds were mainly from the westerly semicircle, north and north-easterly winds with high and falling barometer, shifting to northwest and west when the barometer began to rise; rain and mist occurred nearly every day. Fogs were quite frequent, but not of long duration.

"King Edward Cove, South Georgia, was reached on January 12, at $9^h 30^m$ a. m., use being made the last 24 hours of our auxiliary power.

"The *Carnegie* left South Georgia at 7 p. m., January 14, 1916, towed out of harbor against a heavy head-wind by the steam whaler *Fortuna*. During the following days we realized that we were in climatic conditions quite different from those we had experienced previously. Icebergs appeared in increasing numbers, and fog was almost continuous. We will long remember January 18 as the only day during the entire trip of 4 months when we failed to obtain observations of the magnetic declination. The Sun was visible for only 3 seconds during the entire day, giving no opportunity for observations.

"Larger icebergs were seen as we neared Lindsay Island, one looming up through the fog like a vast extent of dark land with the bright ice-blink

[1] See note on p. 297.

reflected from the fog above it. We encountered an ice-stream where small pieces were too numerous to dodge.

"On January 22 we passed along the north coast of Lindsay Island about 3 miles off shore, obtaining a good view of this lonely, desolate place, with its deep mantle of snow and ice, surrounded with the wrecked icebergs that have come to grief on its shoals. A delegation of 6 penguins came out to greet us, the only ones seen in this vicinity.

"The island agrees almost exactly in appearance and outline with the description and sketch given in the British Admiralty's Africa Pilot, Part II, 1910. It was surveyed by the German Deep Sea Expedition of 1898 in the *Valdivia*. They gave the position for its center as latitude 54° 26′ S., longitude 3° 24′ E. Our observations place its center in latitude 54° 29′ S., longitude 3° 27′ E., or about 3 miles from the position assigned by the *Valdivia*. This is a very close check in position for these regions, and we had no difficulty in locating the island. When our reckoning had placed it about 10 miles southeast of the vessel, we were able to locate it in the proper direction by noting the outline of a snow-covered glacier which appeared motionless through the shifting rifts in cloud and fog.

"Some authorities have called this island 'Bouvet Island,' thereby causing a little confusion. H. R. Mill, in his book 'The Siege of the South Pole,' 1905, gives a couple of pages to a description and picture of Lindsay Island, but names it 'Bouvet,' and gives as its position the latitude and longitude quoted above from the British Admiralty Pilot as that of Lindsay. Both books give as their authority the German Deep Sea Expedition of 1898. The British Admiralty Pilot states that 'In November, 1898, the island (Bouvet) was searched for unsuccessfully by Captain Krech, of the German Deep Sea Expedition vessel *Valdivia*. Its position must, therefore, be considered uncertain.' We agree with this conclusion since we check so well the position given by the *Valdivia* to Lindsay Island.

"Stieler's Hand-Atlas, 1907, publishes a map of Bouvet in a small insert with its south polar charts. The position given, the coast outline, and appearance are those of Lindsay Island.

"Did Captains Bouvet and Norris see Lindsay Island or some island that has never been seen again? They reported it, Captain Bouvet in 1739 and Captain Norris in 1825, and placed it in latitude 54° 00′ S. to 54° 15′ S. and in longitude 4° 30′ E. to 5° 00′ E., or about 15 miles north and about 50 miles east of Lindsay. We know that this position is seriously in error, for Cook, Ross, and Moore searched unsuccessfully for this island while on their various Antarctic cruises.

"After taking bearings of Lindsay Island and such views as the weather and clouds permitted, we stood east in the hope of sighting Bouvet Island. Unfortunately, drifting ice, though in small pieces, became so thick that we thought it best to change our course to the north to avoid delay in this locality. So disappeared our chance of sighting either Bouvet or Thompson Islands.

"Shortly after leaving the vicinity of Lindsay Island, it was decided to stand northward toward the Crozet Islands, so as to cut the isogonic lines at a greater angle.

"When within 30 miles of the southwest point of Kerguelen Islands, the weather became unfavorable for making the land, fog set in, and a gale began to blow, with a rapidly falling barometer. The vessel was immediately headed south to avoid outlying dangers and when clear, the course was set toward Heard Island. The season was advancing, and as a large area remained to be covered before our return to Port Lyttelton, a delay of a week

or more in order to land at Kerguelen seemed unwarranted. This was February 6, and in the evening a copper box, tightly sealed, containing abstracts of all results to date, was set adrift on a float. The following was stamped on the copper box with steel dies: 'Mail to the Carnegie Institution, Washington, D. C., U. S. A., from Yacht *Carnegie*, February 6, 1916.' The float was set adrift at 8 p. m. in latitude 50° 14′ S., longitude 68° 19′ E. The only sign of human kind seen during 4 months, except at South Georgia, was a corpse floating in the open sea, about half way between Heard and Kerguelen Islands, far from land. This was on February 7, at latitude 51° 12′ S., longitude 71° 26′ E.

"On February 8 our course was set to the northward to intersect the *Carnegie's* track of 1911, and to determine the average annual changes of the magnetic elements. We made the first intersection in good time, but encountered head winds and later a calm, when attempting to make the second crossing. With the aid of the engine, however, we were able to make the desired point.

"The average annual changes determined were as follows: 17′ in declination, increasing numerically west values, as opposed to 8′ shown on the charts; −2′ in inclination, increasing, numerically, southerly values, and −0.0007 (C. G. S. units) in horizontal intensity, the value of this element decreasing.

"The brief rest in quiet seas and in warm sunshine was very welcome, but the season was advancing and we were obliged to turn southward again and plunge into the dark and stormy regions of the 'roaring forties and furious fifties.' The stormiest period of the trip awaited us. The heaviest gales and roughest seas yet encountered were experienced, but the vessel stood the strain well.

"As the *Carnegie* proceeded south toward the region of Queen Mary Land, the chart errors in declination constantly increased until, in the region of latitude 60° S., longitude 110° E., they reached a maximum of −12° for the United States and British charts, and of −16° for the German chart, *i. e.*, the charts gave values of west declination numerically too small by 12° to 16°.

"On March 23, during magnetic observations in the afternoon, the horizontal intensity ranged from 0.098 to 0.110 C. G. S., indicating a magnetic disturbance of some kind, possibly a region of local disturbance.

"One iceberg was seen on March 1, the only one encountered since January 28. Owing to the decrease in horizontal intensity and the consequent uncertainty of the compasses, it was decided to turn to the northward on this date, latitude 59° 24′ S. having been reached. A few hours before the time set for turning northward a south wind sprang up, so it was well that we had planned to continue no farther in that direction.

"The portion of our route extending into the Australian Bight was accomplished without special difficulty, and the latitude of 39° 29′ S. was reached.

"Going south again, the *Carnegie* sailed as far as latitude 57° 25′ S., obtaining the lowest horizontal intensity that we had yet observed at sea, 0.086 C. G. S. Owing to conditions of weather and lateness of season, it was thought best to head directly for Port Lyttelton, taking into consideration the fact that we would intersect at good angles all isomagnetic lines on the way.

"The Snares were sighted early on the morning of March 29. They were almost exactly where we expected to see them, so we knew that our chronometers were giving us nearly correct longitudes, after 4 months of hard usage and with the wide range in temperature prevailing in the cabin on account of the heating-stove.

"*Observations for intensity and inclination* were taken every day regardless of conditions, even when the vessel was hove to in a hurricane and was being

tossed about like a chip, and mountainous seas were threatening to break through the observing domes. *Magnetic declinations* were observed on all but one day, during the cruise of four months—a remarkable record, considering the prevailing conditions of fog, mist, rain, and snow. This record was made possible only by the constant watchfulness of the entire party and by taking advantage of every opportunity. Considerable time was spent in 'standing by,' waiting for a break in the clouds or fog. Frequently only a small opening in the clouds would be seen approaching the Sun; then the vessel would be directed to the proper heading and all observers would be called to their stations ready to begin observations the moment the Sun appeared. Often the Sun was not seen again during the day.

"I can not speak too highly of the work done by each and every member of the party, as to spirit of cooperation and unfaltering zeal in the face of most trying conditions.

"Gales occurred of force 7 or higher, Beaufort scale, on 52 out of 120 days. On 26 days the gales were very strong, having an estimated force of 9 to 11. We were overtaken by a continual procession of circular storms, moving about the south polar continent from west to east, and were invariably caught in the northern semicircle, as indicated by the barometer changes. A falling barometer always presaged northerly winds shifting to the northwest and blowing hard. As the barometer began to rise, the wind shifted to southwest, blowing a strong gale when the barometer rose rapidly. The temperature of the sea-water was taken every hour during the entire cruise excepting the first few days. The air-temperature averaged about 5° C. We had precipitation of some sort, mist, light rain, fog, rain, hail, or snow, on 100 days out of the 120 days of the voyage. Fog was recorded on 20 days, and snow 16 days.

"We were in the region where icebergs may be encountered for a period of 3½ months, yet saw them on only 24 days, and to the number of only 133, the largest being 5 miles long, and highest being 400 feet high.

"Upon the return to Port Lyttelton (April 1, 1916), there still remained 2 tanks of fresh water on board and potatoes and onions sufficient for 3 more weeks.

"The vessel sustained no serious damage during the trip. The metal fastening of the upper topsail yard broke on January 4, but the yard was successfully lashed to the parral and gave us no further trouble. The bronze rod bob-stay carried away at the forward end on February 24. It was fished up after some difficulty and secured with a deadeye and lanyard. Upon examination in the dry dock, the vessel's hull was found absolutely clean and undamaged, only one sheet of copper near the keel requiring renewal."

After a stay at Lyttelton of nearly 7 weeks, during which the shore observations and instrumental comparisons were repeated at the Christchurch Magnetic Observatory and the vessel was overhauled and outfitted, the *Carnegie* left this port on May 17, 1916, bound for Pago Pago, Samoa. Light head-winds and calms were encountered, so the engine was started to gain an offing, running all night. For 5 days the wind held northeast, forcing the vessel well toward the Chatham Islands. May 22 was repeated where the one hundred and eightieth meridian was crossed. On May 23 favorable winds were encountered for the first time, and for 3 days fair winds were enjoyed. Then northerly winds and calms made it necessary for the course to be taken westward near the Kermadec Islands. On June 1 the wind was again favorable, but thereafter, until arrival at Pago Pago, it was

necessary to sail close-hauled, with northeast to northwest winds. Landfall was made with some difficulty on account of the heavy clouds and squalls hanging over the island. Observations were carried out as usual during the passage. No observations for magnetic declination were obtained on May 30 and June 4 on account of clouds. Considerable lightning and thunder attended the squally weather. The new gooseneck on the upper topsail yard carried away on May 27, and was replaced with the extra one ordered at Lyttelton. The engine was operated to get offshore when leaving Lyttelton, to clear Savage Island, during a calm on June 4, and to enter the harbor of Pago Pago on June 7. The time of passage was 22 days, with a daily run of 118 miles, for a total of 2,600 miles.

The shore observations having been completed, the *Carnegie* left Pago Pago on June 19, under her own power. The engine operated well, taking the vessel out against a stiff head trade-wind.

The wind was too strong outside to allow making to windward of Tutuila, so the *Carnegie* went around the west end. The Union Group was weathered, but the wind broke off to the north of east, compelling the vessel to go to leeward of the main Phœnix Group. The wind held north of east, forcing the *Carnegie* considerably to the westward of the route planned; however, the crossings of previous tracks were made at the points desired. No storms nor calms were encountered.

The hot weather was very trying, but the party, with two or three exceptions, kept well. Magnetic declinations were obtained twice daily with two exceptions. The average difference, without regard to sign, between the results obtained by the two observers at the collimating compass was 3′ for the 51 determinations. This affords some evidence as to the character of the weather and conditions encountered.

Port Apra, Guam, was reached on Monday, July 17, 1916. The total run from Pago Pago was 3,987 miles, giving a daily average of 147 miles for the 27 days of the trip.

At Port Apra connection was made with the *Galilee* observations of 1907 and extensive intercomparisons of all instruments were made. The *Carnegie* sailed from Port Apra on August 7, bound for San Francisco, where she arrived on September 21. The track followed was arranged to cross as frequently as possible the previous tracks of the *Galilee* and the *Carnegie* and to obtain additional magnetic data in regions most needed. The following quotation is taken from the Commander's report:

"We left the mooring buoy at 1 p. m. on August 7, with our engine running, and being towed by two powerful steam launches belonging to the beach master. Shortly after leaving the buoy, about half-way out of the harbor, a heavy squall came up from ahead and we were unable to make headway against it. After some difficulty we returned to the anchorage and dropped anchor. In the meantime, in response to our signal, the Navy tug *Piscataqua* was preparing to take us in tow. As she had moved from her anchorage to our mooring buoy at 1 p. m., she already had steam up. At 3^h 50^m p. m. we were safely outside the harbor and on our way.

"For 7 days we had continuous heavy gales from the southwest, obliging us to heave to for 2 days in succession, August 9 and 10. We were thus driven northward and compelled to follow very closely the *Galilee's* track from Guam to Japan, up to the point where our various tracks intersect. This was the worst spell of bad weather thus far encountered. Since August 17 we have had moderate weather. There have been considerable fog and cloudiness, but we have succeeded in getting observations for declination daily with four exceptions. The engine has been operated frequently, for a total of 90 hours, during calms and for swinging ship. On August 26 the vessel was swung for intensity and inclination observations, both helms. On August 27 a declination-swing was started, but clouds interrupted the work after 5 headings had been completed. Fog was recorded on 12 days, and rain or mist on 34 days.

"On September 20 we were becalmed off the coast of California, so the engine was put into operation and we came into San Francisco under our own power September 21, after a 20-hour run. We were fortunate in picking up Point Reyes at 1 a. m., before the fog closed down. From there we crept through the fog until we heard the light vessel and picked up a pilot, making the entrance through the fog under our own power. The total distance run from Guam to San Francisco was 5,937 miles. As the time of passage was 46 days, the average daily run was 129 miles. The chronometers were found in error only $8^s.7$."

As heretofore, the *Carnegie's* staff is indebted for special courtesies shown at the ports visited and for valuable assistance rendered by various persons and officials.

The ship's personnel, during the period November 1915 to October 1916, was as follows: J. P. Ault, magnetician and in command of vessel; Dr. H. M. W. Edmonds, magnetician and surgeon, and second in command; H. F. Johnston (to April 1916), I. A. Luke, F. C. Loring and B. Jones (from April 1916), observers; N. Meisenhelter, stenographer-recorder; R. P. Doran (until April 1916), first watch officer; A. Beech (from April 1916), first watch officer; M. G. R. Savary, engineer; M. Hedlund and L. Larsen, second and third watch officers, respectively; C. Heckendorn, mechanic; 8 seamen, 2 cooks, and 2 cabin boys; the complete personnel at any time consisted of 23 persons. [Before the *Carnegie* sailed from San Francisco on November 1, 1916, Observers Luke and Loring were succeeded by Observers A. D. Power and L. L. Tanguy.]

For an account of the atmospheric-electric work aboard the *Carnegie*, see page 332.

It was an interesting circumstance that while the *Carnegie* was at San Francisco during October, the *Galilee*, chartered for the first ocean magnetic work of the Department, was berthed alongside the same pier for a week or more. She is now a three-masted schooner, engaged in the Alaska trade.

Tables 1, 2, and 3 contain a summary of the magnetic declinations and chart corrections observed on the *Carnegie* from August 1915 to September 1916. The chart corrections, in general, do not exceed 2° to 3°, however, for the *Carnegie's* sub-Antarctic voyage; they amount to 5° and 6°, and even 12° to 16° off Southwest Australia.

TABLE 1.—*Magnetic declinations and chart corrections observed on the Carnegie from Dutch Harbor, Alaska, to Lyttelton, New Zealand, August to November 1915.*[1]

Observers: J. P. Ault, commanding the *Carnegie;* H. M. W. Edmonds, I. A. Luke, H. F. Johnston, and H. E. Sawyer. *Minus sign indicates west declination; plus indicates east declination.*

Date.	Position.		Carnegie.	Chart values.			Chart corrections.		
	Lat.	Long.		Brit.[2]	Ger.[3]	U. S.[4]	Brit.	Ger.	U. S.
1915	° ′	° ′	°	°	°	°	°	°	°
Aug. 7	57 37 N	166 58 W	+16.4	+16.8	+16.9	+16.7	−0.4	−0.5	−0.3
8	58 07 N	166 48 W	+16.4	+17.0	+17.1	+16.8	−0.6	−0.7	−0.4
8	57 55 N	168 22 W	+15.1	+16.2	+16.0	+16.0	−1.1	−0.9	−0.9
8	57 53 N	168 34 W	+14.7	+16.0	+15.9	+15.9	−1.3	−1.2	−1.2
9	57 40 N	169 01 W	+15.4	+15.8	+15.6	+15.6	−0.4	−0.2	−0.2
10	59 05 N	171 29 W	+15.4	+14.7	+14.9	+14.4	+0.7	+0.5	+1.0
10	59 01 N	172 24 W	+13.5	+14.1	+14.4	+13.8	−0.6	−0.9	−0.3
11	59 26 N	172 40 W	+12.5	+14.0	+14.3	+13.8	−1.5	−1.8	−1.3
11	59 29 N	174 00 W	+11.4	+13.2	+13.6	+13.0	−1.8	−2.2	−1.6
12	59 01 N	176 17 W	+11.6	+11.7	+11.7	+11.4	−0.1	−0.1	+0.2
12	58 36 N	177 39 W	+ 9.4	+10.8	+10.9	+10.4	−1.4	−1.5	−1.0
12	58 30 N	177 58 W	+10.2	+10.6	+10.6	+10.1	−0.4	−0.4	+0.1
13	57 49 N	179 42 W	+ 9.2	+ 9.4	+ 9.2	+ 9.1	−0.2	0.0	+0.1
13	56 57 N	178 36 E	+ 7.6	+ 8.2	+ 8.1	+ 8.2	−0.6	−0.5	−0.6
15	56 44 N	177 05 E	+ 6.7	+ 7.4	+ 6.9	+ 7.4	−0.7	−0.2	−0.7
15	56 28 N	177 02 E	+ 6.9	+ 7.3	+ 6.8	+ 7.3	−0.4	+0.1	−0.4
16	55 49 N	175 37 E	+ 6.1	+ 6.4	+ 6.2	+ 6.5	−0.3	−0.1	−0.4
16	55 28 N	174 01 E	+ 4.8	+ 5.5	+ 5.1	+ 5.4	−0.7	−0.3	−0.6
17	54 35 N	173 21 E	+ 4.7	+ 5.1	+ 4.8	+ 5.0	−0.4	−0.1	−0.3
17	53 35 N	171 55 E	+ 3.7	+ 4.2	+ 4.0	+ 4.1	−0.5	−0.3	−0.4
18	52 22 N	170 18 E	+ 3.3	+ 3.4	+ 3.3	+ 3.4	−0.1	0.0	−0.1
19	51 13 N	168 38 E	+ 2.2	+ 2.6	+ 2.6	+ 2.6	−0.4	−0.4	−0.4
20	49 46 N	168 16 E	+ 1.9	+ 2.4	+ 2.5	+ 2.5	−0.5	−0.6	−0.6
21	48 14 N	168 22 E	+ 1.7	+ 2.7	+ 2.6	+ 2.7	−1.0	−0.9	−1.0
21	48 04 N	167 43 E	+ 2.1	+ 2.3	+ 2.4	+ 2.4	−0.2	−0.3	−0.3
22	47 27 N	166 45 E	+ 1.7	+ 1.8	+ 2.0	+ 2.0	−0.1	−0.3	−0.3
22	46 39 N	165 52 E	+ 1.2	+ 1.5	+ 1.8	+ 1.7	−0.3	−0.6	−0.5
23	45 48 N	164 43 E	+ 0.8	+ 1.0	+ 1.5	+ 1.4	−0.2	−0.7	−0.6
23	45 20 N	164 00 E	+ 0.7	+ 0.8	+ 1.2	+ 1.1	−0.1	−0.5	−0.4
24	45 00 N	163 18 E	+ 0.7	+ 0.5	+ 1.0	+ 0.9	+0.2	−0.3	−0.2
24	44 38 N	162 48 E	+ 0.3	+ 0.5	+ 1.0	+ 0.7	−0.2	−0.7	−0.4
25	44 32 N	162 49 E	+ 0.2	+ 0.5	+ 1.0	+ 0.7	−0.3	−0.8	−0.5
25	44 21 N	163 10 E	+ 0.4	+ 0.7	+ 1.0	+ 1.0	−0.3	−0.6	−0.6
26	40 33 N	163 35 E	+ 1.2	+ 1.9	+ 1.8	+ 1.7	−0.7	−0.6	−0.5
27	39 31 N	163 49 E	+ 1.8	+ 2.1	+ 2.3	+ 2.0	−0.3	−0.5	−0.2
27	38 15 N	164 13 E	+ 2.2	+ 2.8	+ 2.8	+ 2.3	−0.6	−0.6	−0.1
27	37 50 N	164 16 E	+ 2.1	+ 2.9	+ 3.0	+ 2.4	−0.8	−0.9	−0.3
28	36 51 N	164 28 E	+ 2.4	+ 3.1	+ 3.2	+ 2.7	−0.7	−0.8	−0.3
28	36 08 N	165 25 E	+ 3.1	+ 3.7	+ 3.7	+ 3.3	−0.6	−0.6	−0.2
29	35 13 N	166 42 E	+ 4.0	+ 4.4	+ 4.4	+ 4.1	−0.4	−0.4	−0.1
29	34 54 N	168 07 E	+ 4.2	+ 5.0	+ 5.1	+ 4.9	−0.8	−0.9	−0.7
30	34 26 N	169 44 E	+ 5.5	+ 5.8	+ 5.8	+ 5.6	−0.3	−0.3	−0.1
30	33 22 N	170 30 E	+ 5.6	+ 6.3	+ 6.2	+ 6.0	−0.7	−0.6	−0.4
31	32 16 N	170 48 E	+ 6.1	+ 6.5	+ 6.6	+ 6.3	−0.4	−0.5	−0.2
31	31 13 N	171 10 E	+ 6.3	+ 6.9	+ 6.8	+ 6.6	−0.6	−0.5	−0.3

[1]For previous tables, see *Terr. Mag.*, v. 15, pp. 57–82, 129–144; v. 16, pp. 133–136; v. 17, pp. 31–32, 97–101, 141–144, 179–180; v. 18, pp. 63–64, 111–112, 161–162; v. 19, pp. 38, 126, 204, 234–235; v. 20, pp. 69–70, 104; also Annual Report for 1915, pp. 320–322.

[2]From British Admiralty Chart No. 2598 for 1912, referred to 1915.

[3]From Reichs-Marine-Amt Chart, Tit. XIV, No. 2, for 1910, referred to 1915 by means of the secular change given on the U. S. Chart.

[4]From U. S. Hydrographic Office Chart No. 2406 for 1915.

TABLE 1.—*Magnetic declinations and chart corrections observed on the Carnegie from Dutch Harbor, Alaska, to Lyttelton, New Zealand, August to November 1915*—continued.

Date.	Position.		Carnegie.	Chart values.			Chart corrections.		
	Lat.	Long.		Brit.	Ger.	U. S.	Brit.	Ger.	U. S.
1915	° ′	° ′	°	°	°	°	°	°	°
Sept. 1	30 28 N	171 18 E	+6.8	+7.1	+7.0	+6.7	−0.3	−0.2	+0.1
1	30 02 N	171 06 E	+6.9	+7.1	+7.0	+6.8	−0.2	−0.1	+0.1
2	29 18 N	170 42 E	+6.6	+7.1	+6.9	+6.7	−0.5	−0.3	−0.1
2	28 57 N	170 35 E	+6.4	+7.1	+6.9	+6.7	−0.7	−0.5	−0.3
3	28 39 N	170 16 E	+6.8	+7.0	+6.8	+6.6	−0.2	0.0	+0.2
3	27 59 N	170 04 E	+6.4	+7.1	+6.8	+6.6	−0.7	−0.4	−0.2
3	27 41 N	170 01 E	+6.6	+7.2	+6.9	+6.6	−0.6	−0.3	0.0
4	27 17 N	169 49 E	+6.6	+7.2	+6.8	+6.6	−0.6	−0.2	0.0
4	26 44 N	169 23 E	+6.4	+7.0	+6.8	+6.6	−0.6	−0.4	−0.2
4	25 37 N	168 35 E	+6.4	+7.0	+6.7	+6.5	−0.6	−0.3	−0.1
5	23 19 N	167 30 E	+6.5	+7.0	+6.7	+6.5	−0.5	−0.2	0.0
5	21 56 N	167 02 E	+6.3	+7.1	+6.8	+6.6	−0.8	−0.5	−0.3
7	21 27 N	169 07 E	+6.8	+7.7	+7.4	+7.2	−0.9	−0.6	−0.4
7	21 31 N	169 22 E	+7.0	+7.8	+7.5	+7.3	−0.8	−0.5	−0.3
8	21 21 N	169 47 E	+7.4	+7.9	+7.6	+7.4	−0.5	−0.2	0.0
9	21 02 N	168 32 E	+7.1	+7.5	+7.2	+7.1	−0.4	−0.1	0.0
10	20 40 N	168 13 E	+7.0	+7.4	+7.2	+7.1	−0.4	−0.2	−0.1
10	20 37 N	168 04 E	+6.9	+7.4	+7.2	+7.1	−0.5	−0.3	−0.2
11	20 18 N	167 41 E	+7.0	+7.4	+7.1	+7.0	−0.4	−0.1	0.0
11	19 44 N	166 55 E	+6.6	+7.3	+7.0	+6.9	−0.7	−0.4	−0.3
12	19 14 N	166 28 E	+7.0	+7.2	+6.9	+6.9	−0.2	+0.1	+0.1
12	18 36 N	166 06 E	+6.6	+7.2	+6.9	+6.8	−0.6	−0.3	−0.2
13	17 32 N	165 33 E	+6.6	+7.2	+7.1	+6.8	−0.6	−0.5	−0.2
13	16 34 N	165 21 E	+7.1	+7.3	+7.1	+6.9	−0.2	0.0	+0.2
14	15 29 N	165 17 E	+6.7	+7.4	+7.2	+7.0	−0.7	−0.5	−0.3
14	14 33 N	165 11 E	+6.6	+7.4	+7.2	+7.0	−0.8	−0.6	−0.4
15	14 13 N	164 50 E	+6.9	+7.3	+7.2	+7.0	−0.4	−0.3	−0.1
15	14 16 N	165 01 E	+6.7	+7.4	+7.2	+7.0	−0.7	−0.5	−0.3
16	14 00 N	165 33 E	+6.9	+7.5	+7.4	+7.2	−0.6	−0.5	−0.3
16	13 47 N	166 16 E	+7.2	+7.6	+7.6	+7.3	−0.4	−0.4	−0.1
17	13 46 N	166 24 E	+7.1	+7.7	+7.7	+7.4	−0.6	−0.6	−0.3
17	13 21 N	165 58 E	+7.0	+7.6	+7.5	+7.3	−0.6	−0.5	−0.3
18	12 29 N	165 01 E	+7.2	+7.5	+7.4	+7.2	−0.3	−0.2	0.0
18	11 57 N	164 32 E	+6.1[1]	+7.4	+7.3	+7.1	−1.3	−1.2	−1.0
19	11 31 N	164 23 E	+7.1	+7.4	+7.3	+7.2	−0.3	−0.2	−0.1
19	11 13 N	164 12 E	+6.8	+7.4	+7.3	+7.2	−0.6	−0.5	−0.4
20	10 40 N	164 06 E	+7.0	+7.4	+7.3	+7.2	−0.4	−0.3	−0.2
20	9 46 N	163 56 E	+6.8	+7.4	+7.3	+7.2	−0.6	−0.5	−0.4
21	9 17 N	163 41 E	+7.0	+7.4	+7.3	+7.2	−0.4	−0.3	−0.2
21	8 40 N	163 29 E	+6.8	+7.4	+7.3	+7.3	−0.6	−0.5	−0.5
22	8 06 N	163 32 E	+7.1	+7.4	+7.3	+7.4	−0.3	−0.2	−0.3
22	7 45 N	163 47 E	+6.8	+7.5	+7.5	+7.5	−0.7	−0.7	−0.7
23	7 19 N	164 05 E	+7.2	+7.6	+7.6	+7.5	−0.4	−0.4	−0.3
23	6 42 N	164 20 E	+7.2	+7.7	+7.8	+7.6	−0.5	−0.6	−0.4
24	5 56 N	164 38 E	+7.6	+7.7	+7.9	+7.8	−0.1	−0.3	−0.2
24	4 56 N	164 33 E	+7.6	+7.8	+8.0	+7.8	−0.2	−0.4	−0.2
25	4 23 N	164 14 E	+7.4	+7.8	+7.9	+7.8	−0.4	−0.5	−0.4
25	4 16 N	163 54 E	+7.2	+7.8	+7.9	+7.8	−0.6	−0.7	−0.6
26	4 04 N	163 50 E	+7.4	+7.8	+7.9	+7.8	−0.4	−0.5	−0.4
27	3 40 N	163 56 E	+7.3	+7.8	+7.9	+7.8	−0.5	−0.6	−0.5
27	3 36 N	163 45 E	+7.3	+7.8	+7.9	+7.9	−0.5	−0.6	−0.6
28	3 25 N	163 02 E	+7.3	+7.7	+7.8	+7.8	−0.4	−0.5	−0.5
28	3 11 N	162 42 E	+7.2	+7.7	+7.7	+7.7	−0.5	−0.5	−0.5
29	3 01 N	162 05 E	+7.2	+7.6	+7.6	+7.6	−0.4	−0.4	−0.4
29	2 56 N	162 05 E	+7.1	+7.6	+7.5	+7.6	−0.5	−0.4	−0.5
30	2 28 N	161 53 E	+7.1	+7.6	+7.5	+7.6	−0.5	−0.4	−0.5

[1]Local disturbance; near Marshall Island Atoll.

TABLE 1.—*Magnetic declinations and chart corrections observed on the Carnegie from Dutch Harbor, Alaska, to Lyttelton, New Zealand, August to November 1915*—concluded.

Date.	Position.		Carnegie.	Chart values.			Chart corrections.		
	Lat.	Long.		Brit.	Ger.	U. S.	Brit.	Ger.	U. S.
1915	° ′	° ′	°	°	°	°	°	°	°
Sept. 30	2 20 N	161 32 E	+6.9	+7.6	+7.5	+7.6	−0.7	−0.6	−0.7
Oct. 1	1 55 N	160 34 E	+6.9	+7.4	+7.4	+7.5	−0.5	−0.5	−0.6
1	2 05 N	160 50 E	+6.8	+7.4	+7.4	+7.6	−0.6	−0.6	−0.8
2	1 01 N	160 07 E	+6.8	+7.5	+7.4	+7.5	−0.7	−0.6	−0.7
2	0 04 S	159 50 E	+6.8	+7.5	+7.4	+7.6	−0.7	−0.6	−0.8
3	1 31 S	159 43 E	+6.9	+7.6	+7.5	+7.7	−0.7	−0.6	−0.8
3	2 40 S	160 11 E	+7.3	+7.8	+7.8	+7.9	−0.5	−0.5	−0.6
4	3 46 S	160 54 E	+7.4	+8.0	+8.0	+8.0	−0.6	−0.6	−0.6
4	4 29 S	161 21 E	+7.4	+8.1	+8.1	+8.1	−0.7	−0.7	−0.7
5	4 58 S	161 48 E	+7.6	+8.2	+8.1	+8.1	−0.6	−0.5	−0.5
6	5 56 S	163 36 E	+8.2	+8.4	+8.4	+8.3	−0.2	−0.2	−0.1
7	6 31 S	164 03 E	+8.0	+8.6	+8.5	+8.3	−0.6	−0.5	−0.3
8	7 20 S	163 25 E	+8.0	+8.6	+8.5	+8.5	−0.6	−0.5	−0.5
8	8 08 S	163 09 E	+8.2	+8.6	+8.5	+8.6	−0.4	−0.3	−0.4
9	9 09 S	162 50 E	+8.5	+8.7	+8.6	+8.6	−0.2	−0.1	−0.1
9	9 44 S	162 36 E	+8.1	+8.7	+8.6	+8.7	−0.6	−0.5	−0.6
11	11 20 S	162 31 E	+8.3	+8.8	+8.6	+8.8	−0.5	−0.3	−0.5
11	12 12 S	161 28 E	+8.2	+8.8	+8.6	+8.8	−0.6	−0.4	−0.6
12	12 24 S	161 22 E	+8.2	+8.8	+8.6	+8.8	−0.6	−0.4	−0.6
12	13 01 S	160 42 E	+8.2	+8.8	+8.6	+8.8	−0.6	−0.4	−0.6
13	13 52 S	159 58 E	+8.2	+8.8	+8.6	+8.8	−0.6	−0.4	−0.6
13	14 14 S	159 19 E	+8.0	+8.8	+8.6	+8.8	−0.8	−0.6	−0.8
14	15 33 S	158 41 E	+7.9	+8.9	+8.7	+8.8	−1.0	−0.8	−0.9
14	17 02 S	158 08 E	+8.1	+8.9	+8.8	+8.9	−0.8	−0.7	−0.8
15	18 37 S	157 46 E	+8.4	+9.0	+8.9	+9.0	−0.6	−0.5	−0.6
15	20 16 S	157 24 E	+8.3	+9.2	+9.0	+9.2	−0.9	−0.7	−0.9
16	21 34 S	157 22 E	+9.0	+9.3	+9.2	+9.4	−0.3	−0.2	−0.4
16	21 50 S	157 05 E	+8.9	+9.3	+9.2	+9.4	−0.4	−0.3	−0.5
17	22 07 S	156 51 E	+9.0	+9.3	+9.3	+9.4	−0.3	−0.3	−0.4
18	23 10 S	157 00 E	+8.7	+9.5	+9.5	+9.5	−0.8	−0.8	−0.8
18	23 43 S	157 00 E	+9.0	+9.6	+9.5	+9.6	−0.6	−0.5	−0.6
19	23 55 S	156 50 E	+9.0	+9.6	+9.5	+9.6	−0.6	−0.5	−0.6
20	25 43 S	155 33 E	+9.1	+9.6	+9.6	+9.6	−0.5	−0.5	−0.5
20	26 38 S	154 57 E	+8.7	+9.7	+9.6	+9.7	−1.0	−0.9	−1.0
21	27 34 S	154 32 E	+9.6	+9.7	+9.6	+9.7	−0.1	0.0	−0.1
21	28 35 S	154 30 E	+9.4	+9.9	+9.8	+9.9	−0.5	−0.4	−0.5
22	29 43 S	155 12 E	+9.5	+10.1	+10.1	+10.2	−0.6	−0.6	−0.7
22	30 48 S	155 54 E	+10.0	+10.5	+10.5	+10.5	−0.5	−0.5	−0.5
23	32 19 S	156 59 E	+10.6	+11.0	+11.0	+11.0	−0.4	−0.4	−0.4
23	33 48 S	157 34 E	+11.1	+11.4	+11.4	+11.5	−0.3	−0.3	−0.4
24	35 32 S	158 14 E	+11.5	+12.1	+12.0	+12.0	−0.6	−0.5	−0.5
24	35 54 S	158 48 E	+11.7	+12.2	+12.2	+12.2	−0.5	−0.5	−0.5
25	36 22 S	159 51 E	+12.9	+12.7	+12.7	+12.7	+0.2	+0.2	+0.2
26	37 00 S	160 40 E	+13.0	+13.1	+13.1	+13.1	−0.1	−0.1	−0.1
26	37 27 S	161 27 E	+13.0	+13.4	+13.4	+13.4	−0.4	−0.4	−0.4
27	38 12 S	161 47 E	+13.3	+13.7	+13.7	+13.7	−0.4	−0.4	−0.4
27	38 41 S	161 52 E	+13.2	+13.9	+13.9	+13.9	−0.7	−0.7	−0.7
28	39 14 S	161 57 E	+13.5	+14.1	+14.1	+14.0	−0.6	−0.6	−0.5
28	39 35 S	162 10 E	+14.0	+14.2	+14.2	+14.2	−0.2	−0.2	−0.2
29	41 57 S	162 26 E	+14.7	+15.1	+15.0	+15.1	−0.4	−0.3	−0.4
29	42 31 S	162 42 E	+15.0	+15.5	+15.2	+15.4	−0.5	−0.2	−0.4
30	43 58 S	163 29 E	+15.7	+16.4	+15.9	+16.2	−0.7	−0.2	−0.5
30	45 36 S	164 53 E	+16.4	+17.5	+17.0	+17.3	−1.1	−0.6	−0.9
31	46 31 S	167 20 E	+16.8	+17.9	+18.1	+18.0	−1.1	−1.3	−1.2
Nov. 2	45 14 S	172 00 E	+17.7	+18.2	+18.4	+18.0	−0.5	−0.7	−0.3
2	44 16 S	172 50 E	+17.2	+17.5	+18.1	+17.5	−0.3	−0.9	−0.3
3	43 42 S	172 59 E	+17.1	+17.1	+17.8	+17.3	0.0	−0.7	−0.2

TABLE 2.—*Magnetic declinations and chart corrections observed on the Carnegie from Lyttelton, New Zealand, to South Georgia, and thence to Lyttelton, December 1915 to April 1916.*[1]

Observers: J. P. Ault, commanding the *Carnegie;* H. M. W. Edmonds, I. A. Luke, H. F. Johnston, and F. C. Loring. *Minus indicates west declination; plus indicates east declination.*

Date.	Position.		Carnegie.	Chart values.			Chart corrections.		
	Lat.	Long.		Brit.[2]	Ger.[3]	U. S.[4]	Brit.	Ger.	U. S.
1915	° ′	° ′	°	°	°	°	°	°	°
Dec. 6	43 47 S	173 20 E	+17.1	+17.1	+17.9	+17.2	0.0	−0.8	−0.1
7	46 04 S	174 39 E	+17.9	+18.7	+19.2	+18.6	−0.8	−1.3	−0.7
8	47 37 S	176 16 E	+18.3	+19.6	+20.1	+19.7	−1.3	−1.8	−1.4
9	49 03 S	178 20 E	+18.5	+20.3	+20.9	+20.7	−1.8	−2.4	−2.2
9	49 23 S	179 13 E	+20.4	+20.4	+21.1	+20.9	0.0	−0.7	−0.5
9	49 56 S	179 13 W	+20.4	+20.7	+21.4	+21.1	−0.3	−1.0	−0.7
9	50 28 S	177 34 W	+21.5	+21.0	+21.7	+21.4	+0.5	−0.2	+0.1
9	50 34 S	177 17 W	+20.9	+21.1	+21.8	+21.5	−0.2	−0.9	−0.6
10	51 29 S	175 47 W	+21.3	+21.6	+22.1	+22.0	−0.3	−0.8	−0.7
11	53 03 S	173 42 W	+22.4	+22.7	+22.9	+22.9	−0.3	−0.5	−0.5
11	53 34 S	172 43 W	+21.5	+23.0	+23.1	+23.3	−1.5	−1.6	−1.8
11	53 51 S	172 16 W	+22.0	+23.1	+23.2	+23.5	−1.1	−1.2	−1.5
12	54 18 S	171 42 W	+22.1	+23.4	+23.4	+23.8	−1.3	−1.3	−1.7
12	53 44 S	170 13 W	+22.3	+22.7	+22.7	+23.3	−0.4	−0.4	−1.0
13	54 12 S	168 50 W	+22.6	+22.9	+22.9	+23.6	−0.3	−0.3	−1.0
13	54 46 S	167 46 W	+23.3	+24.2	+23.2	+24.0	−0.9	+0.1	−0.7
14	55 12 S	166 25 W	+22.9	+23.5	+23.3	+24.4	−0.6	−0.4	−1.5
14	55 29 S	164 22 W	+23.5	+23.6	+23.3	+24.6	−0.1	+0.2	−1.1
14	55 43 S	163 26 W	+23.0	+23.7	+23.3	+24.8	−0.7	−0.3	−1.8
15	56 00 S	162 33 W	+24.3	+23.8	+23.4	+25.1	+0.5	+0.9	−0.8
15	56 08 S	161 36 W	+24.0	+23.9	+23.5	+25.3	+0.1	+0.5	−1.3
16	57 36 S	157 14 W	+25.7	+24.8	+24.1	+26.6	+0.9	+1.6	−0.9
17	58 25 S	155 38 W	+26.8	+25.5	+24.8	+27.2	+1.3	+2.0	−0.4
17	59 26 S	153 42 W	+27.0	+26.6	+25.8	+28.1	+0.4	+1.2	−1.1
18	60 16 S	151 18 W	+29.5	([5])	([5])	([5])	....	....	....
19	60 18 S	147 18 W	+29.3	([5])	([5])	([5])	....	....	....
19	60 20 S	144 29 W	+30.7	([5])	([5])	([5])	....	....	....
20	60 26 S	141 11 W	+30.6	([5])	([5])	([5])	....	....	....
20	60 32 S	138 52 W	+30.9	([5])	([5])	([5])	....	....	....
21	60 09 S	132 28 W	+30.4	([5])	([5])	([5])	....	....	....
22	59 46 S	129 28 W	+30.9	+28.1	+27.6	+31.0	+2.8	+3.3	−0.1
22	59 40 S	128 49 W	+30.8	+28.1	+27.8	+31.1	+2.7	+3.0	−0.3
22	59 38 S	127 16 W	+32.0	+28.2	+27.9	+31.5	+3.8	+4.1	+0.5
23	60 32 S	124 04 W	+32.7	([5])	([5])	([5])	....	....	....
24	60 06 S	124 21 W	+32.4	([5])	([5])	([5])	....	....	....
24	59 37 S	123 26 W	+31.6	+28.8	+28.7	+32.4	+2.8	+2.9	−0.8
25	59 14 S	118 26 W	+31.7	+29.2	+29.6	+32.3	+2.5	+2.1	−0.6
25	59 10 S	115 51 W	+31.7	+29.7	+30.1	+32.2	+2.0	+1.6	−0.5
26	59 08 S	112 20 W	+31.4	+30.5	+30.7	+32.2	+0.9	+0.7	−0.8
26	59 06 S	109 44 W	+31.3	+31.1	+31.3	+32.1	+0.2	0.0	−0.8
26	59 05 S	108 44 W	+31.6	+31.2	+31.6	+32.0	+0.4	0.0	−0.4
27	59 07 S	105 37 W	+31.9	+31.7	+32.0	+31.7	+0.2	−0.1	+0.2
27	59 07 S	102 24 W	+31.0	+31.0	+32.0	+31.1	0.0	−1.0	−0.1
27	59 03 S	101 26 W	+30.7	+30.8	+32.0	+30.8	−0.1	−1.3	−0.1
28	58 54 S	99 00 W	+31.0	+30.3	+31.5	+30.1	+0.7	−0.5	+0.9

[1]The narrative of this cruise will be found on pages 297–301. For previous tables, see footnote 1, Table 1.

[2]From British Admiralty Chart No. 2598 for 1912 with secular change data applied except in region south of 40° south latitude and between 0° and 105° east longitude.

[3]From Reichs-Marine-Amt Chart, Tit. XIV, No. 2 for 1910, with secular change data applied, except in region south of 40° south latitude and between 0° and 100° east longitude.

[4]From U. S. Hydrographic Office Chart No. 2406 for 1915.

[5]Beyond the chart limits.

TABLE 2.—*Magnetic declinations and chart corrections observed on the Carnegie from Lyttelton, New Zealand, to South Georgia, thence to Lyttelton, December 1915 to April 1916*—cont.

Date.	Position.		Carnegie.	Chart values.			Chart corrections.		
	Lat.	Long.		Brit.	Ger.	U. S.	Brit.	Ger.	U. S.
1915	° ′	° ′	°	°	°	°	°	°	°
Dec. 28	58 48 S	95 55 W	+30.4	+29 8	+30 8	+29 4	+0.6	−0 4	+1.0
28	58 48 S	94 59 W	+30.2	+29 6	+30 7	+29 3	+0.6	−0.5	+0.9
29	58 48 S	92 28 W	+29.1	+29 0	+30.0	+28.7	+0 1	−0.9	+0.4
29	58 48 S	90 30 W	+28 8	+28 6	+29 3	+28 1	+0 2	−0.5	+0 7
30	58 48 S	89 46 W	+28.6	+28 4	+29 1	+27.9	+0.2	−0.5	+0.7
30	58 49 S	87 52 W	+27.8	+27 8	+28.3	+27 4	0.0	−0 5	+0.4
31	58 50 S	86 58 W	+27 9	+27.6	+28 1	+27.2	+0 3	−0 2	+0 7
31	59 08 S	84 23 W	+26.8	+26.9	+27.2	+26 6	−0 1	−0 4	+0.2
1916									
Jan. 1	59 12 S	82 21 W	+25.8	+26 1	+26.3	+26 0	−0 3	−0 5	−0.2
1	59 22 S	79 21 W	+24.7	+25 1	+25.1	+25 3	−0.4	−0 4	−0.6
2	59 58 S	75 29 W	+22 7	+23.7	+23 3	+23 7	−1 0	−0.6	−1 0
2	60 08 S	73 40 W	+22 4	(1)	(1)	(1)	....	....	....
3	59 56 S	70 18 W	+20.4	+21 3	+20.2	+20 7	−0 9	+0 2	−0.3
3	59 41 S	68 20 W	+18 7	+20 2	+18 9	+19 5	−1.5	−0 2	−0.8
3	59 41 S	67 21 W	+19.1	+19 7	+18 2	+18.9	−0 6	+0 9	+0.2
4	59 53 S	65 55 W	+17.8	+18 8	+17.5	+18 0	−1 0	+0.3	−0 2
5	59 33 S	64 01 W	+16 5	+17.5	+16 4	+16 8	−1.0	+0.1	−0.3
5	59 12 S	62 06 W	+15.1	+15.7	+15.1	+15 6	−0 6	0 0	−0.5
5	59 04 S	61 09 W	+14 2	+14 8	+14.4	+14 8	−0 6	−0 2	−0 6
6	58 47 S	59 18 W	+13 8	+13 4	+13 1	+13.4	+0 4	+0 7	+0 4
7	58 00 S	53 07 W	+ 8 8	+ 9 4	+ 9 1	+ 9 0	−0 6	−0 3	−0 2
7	57 26 S	51 02 W	+ 7 4	+ 7 7	+ 7 5	+ 7 2	−0 3	−0 1	+0 2
8	56 20 S	46 54 W	+ 3 9	+ 4 1	+ 4 1	+ 4 0	−0 2	−0 2	−0 1
9	55 35 S	44 42 W	+ 2 4	+ 2 2	+ 2 3	+ 2 3	+0.2	+0 1	+0.1
10	54 18 S	40 43 W	− 1 4	− 1 6	− 1.0	− 1.0	+0.2	−0.4	−0 4
11	54 09 S	38 23 W	− 3 4	− 3 3	− 2 6	− 2.6	−0 1	−0 8	−0.8
11	53 54 S	38 14 W	− 3.1	− 3 5	− 2 7	− 2 7	+0 4	−0.4	−0 4
11	53 54 S	37 54 W	− 3 6	− 3 8	− 3 0	− 3 2	+0 2	−0.6	−0.4
12	54 16 S	36 20 W	− 4 7	− 4 9	− 3 7	− 4 0	+0 2	−1.0	−0 7
15	54 14 S	34 33 W	− 5 7	− 6 0	− 5 3	− 5 3	+0 3	−0 4	−0.4
15	54 14 S	33 57 W	− 6 2	− 6 4	− 5 4	− 5.8	+0 2	−0 8	−0.4
15	54 19 S	31 22 W	− 7 7	− 8 3	− 7 1	− 7 5	+0 6	−0 6	−0 2
16	54 41 S	27 58 W	−10 6	−10 2	− 9 4	− 9 5	−0 4	−1.2	−1.1
17	54 34 S	25 12 W	−12 1	−12 2	−11 3	−11 3	+0 1	−0.8	−0 8
19	54 30 S	15 38 W	−17 3	−18.2	−17 0	−17 5	+0 9	−0 3	+0 2
19	54 29 S	14 41 W	−17.5	−18 8	−17 4	−18 0	+1 3	−0 1	+0 5
20	54 19 S	10 12 W	−20 0	−21 1	−19 7	−20 5	+1 1	−0 3	+0.5
20	54 18 S	9 32 W	−20.4	−21 4	−20 1	−20 9	+1 0	−0 3	+0.5
20	54 17 S	8 36 W	−20 1	−21.7	−20 5	−21.4	+1 6	+0.4	+1.3
21	53 53 S	1 50 W	−22 8	−24 9	−24 2	−24 4	+2 1	+1 4	+1.6
21	53 45 S	1 23 W	−24 3	−25.2	−24.5	−24.6	+0 9	+0.2	+0.3
22	53 41 S	0 39 E	−25 2	−25 9	−25.3	−25.3	+0 7	+0.1	+0.1
22	54 22 S	2 36 E	−24.7	−26 4	−26.0	−25.7	+1 7	+1.3	+1.0
23	53 48 S	4 19 E	−25.3	−27.2	−27 0	−26.3	+1.9	+1.7	+1.0
23	53 32 S	6 21 E	−26.2	−28.0	−28.1	−27.1	+1.8	+1 9	+0.9
24	53 39 S	9 22 E	−27 1	−29 1	−29 1	−27 9	+2.0	+2 0	+0 8
24	53 47 S	10 54 E	−27 0	−29 5	−29 6	−28 2	+2.5	+2.6	+1.2
25	54 03 S	14 35 E	−28.5	−30 6	−30 6	−29.0	+2.1	+2.1	+0.5
25	54 16 S	16 30 E	−28 4	−31 1	−31.0	−29.4	+2.7	+2.6	+1.0
26	54 33 S	19 55 E	−28 8	−32.0	−31 7	−30.1	+3.2	+2.9	+1.3
26	54 27 S	22 16 E	−29.2	−32 9	−32 2	−30.9	+3.7	+3.0	+1.7
27	54 15 S	26 16 E	−29 6	−34.0	−33.1	−32 1	+4.4	+3.5	+2.5
28	53 56 S	29 43 E	−29 5	−35 0	−33.9	−33.2	+5 5	+4.4	+3.7
28	53 25 S	32 12 E	−29.5	−35.6	−34.4	−33.9	+6 1	+4.9	+4.4

[1]Beyond the chart limits.

TABLE 2.—*Magnetic declinations and chart corrections observed on the Carnegie from Lyttelton, New Zealand, to South Georgia, thence to Lyttelton, Dec. 1915 to Apr. 1916*—cont.

Date.	Position.		Carnegie.	Chart values.			Chart corrections.		
	Lat.	Long.		Brit.	Ger.	U. S.	Brit.	Ger.	U. S.
1916	° ′	° ′	°	°	°	°	°	°	°
Jan. 29	52 55 S	34 55 E	−30 6	−35 7	−34.9	−34.8	+5 1	+4.3	+4.2
29	52 51 S	35 19 E	−30.2	−35.7	−35.0	−35 0	+5.5	+4.8	+4 8
30	52 46 S	38 40 E	−31 3	−35.8	−35 8	−35.4	+4 5	+4.5	+4.1
30	52 42 S	39 52 E	−32.0	−35.7	−36.0	−35.4	+3 7	+4.0	+3.4
31	51 53 S	42 33 E	−31.5	−35 1	−36 4	−35.1	+3.6	+4.9	+3.6
31	51 10 S	44 02 E	−31 3	−34 4	−36.4	−34.4	+3 1	+5.1	+3.1
Feb. 1	50 06 S	46 23 E	−30.8	−33.1	−36.3	−33 5	+2.3	+5 5	+2.7
1	49 18 S	48 17 E	−31 0	−32.4	−36 0	−32 9	+1 4	+5.0	+1.9
2	48 36 S	50 00 E	−30 9	−31 7	−35.7	−32.5	+0 8	+4.8	+1.6
2	48 35 S	51 58 E	−31 7	−31 7	−35 8	−32.5	0.0	+4.1	+0 8
2	48 35 S	52 13 E	−31 8	−31 7	−35 9	−32 5	−0 1	+4 1	+0.7
3	48 34 S	54 00 E	−32 1	−31.9	−36 0	−32.6	−0.2	+3 9	+0.5
3	48 34 S	56 08 E	−32.5	−32 2	−36 1	−32 9	−0.3	+3.6	+0.4
4	48 44 S	60 23 E	−35.0	−33 0	−36 5	−33 9	−2 0	+1.5	−1.1
4	48 48 S	60 59 E	−35 1	−33 3	−36 8	−34 1	−1.8	+1.7	−1.0
5	49 00 S	63 29 E	−34 4	−34 2	−36 8	−35 0	−0 2	+2 4	+0.6
5	49 05 S	64 35 E	−36.1	−34 6	−36 9	−35 3	−1 5	+0 8	−0 8
6	49 24 S	66 12 E	−37 7	−35 3	−37 3	−36 0	−2 4	−0 4	−1.7
6	50 09 S	68 01 E	−38 5	−36 3	−38.2	−37 2	−2 2	−0 3	−1 3
7	50 38 S	69 35 E	−39 6	−37 0	−38 9	−37 9	−2 6	−0 7	−1 7
7	51 26 S	72 10 E	−40.6	−38 2	−39 8	−38 9	−2 4	−0 8	−1.7
8	51 42 S	73 22 E	−41 5	−38 6	−40 1	−39 4	−2 9	−1.4	−2 1
8	52 19 S	75 36 E	−43 1	−39 4	−40 6	−40 2	−3 7	−2.5	−2.9
8	52 28 S	76 29 E	−41 7	−39 6	−40 9	−40 5	−2 1	−0 8	−1.2
9	51 41 S	77 12 E	−41 5	−39 0	−39 5	−40 0	−2 5	−2.0	−1.5
9	50 28 S	78 38 E	−42 3	−38 0	−37 9	−39 0	−4 3	−4 4	−3:3
10	49 11 S	81 10 E	−40 2	−37 1	−35 6	−38 1	−3 1	−4 6	−2.1
10	49 06 S	81 16 E	−41.9	−37 0	−35 4	−38.0	−4 9	−6 5	−3.9
11	47 38 S	82 58 E	−39 2	−36 1	−33 4	−36 8	−3 1	−5 8	−2 4
11	46 35 S	84 16 E	−38 0	−35 3	−32 0	−35 8	−2 7	−6 0	−2.2
12	44 39 S	85 58 E	−35 9	−33 4	−29 4	−34 0	−2 5	−6 5	−1 9
12	43 32 S	87 02 E	−34.4	−32 1	−27 5	−32.6	−2.3	−6 9	−1.8
13	41 47 S	88 12 E	−30 8	−30.1	−25 1	−30 6	−0.7	−5 7	−0.2
13	40 48 S	88 51 E	−30 4	−28.3	−23 8	−29 1	−2.1	−6.6	−1.3
13	40 33 S	88 58 E	−29.7	−27 8	−23 6	−28 8	−1.9	−6 1	−0.9
14	39 02 S	89 49 E	−28 0	−26 2	−22 6	−27 1	−1 8	−5.4	−0.9
14	37 45 S	90 53 E	−25 6	−24 5	−20.9	−25.3	−1 1	−4.7	−0.3
14	37 34 S	91 02 E	−26 4	−23 7	−20.4	−25 0	−2.7	−6.0	−1.4
15	35 58 S	92 32 E	−22 9	−21.4	−18 3	−22.7	−1.5	−4.6	−0.2
15	35 41 S	93 33 E	−22.7	−20 6	−17 5	−21 7	−2.1	−5 2	−1.0
15	35 32 S	93 56 E	−21 8	−20 2	−17 0	−21.3	−1 6	−4 8	−0.5
16	34 55 S	95 20 E	−20.5	−18 9	−15 9	−19.8	−1 6	−4.6	−0.7
16	34 09 S	96 23 E	−18.6	−17 8	−14.9	−18.6	−0.8	−3.7	0.0
17	34 54 S	95 36 E	−20.6	−18.7	−15 8	−19.7	−1.9	−4 8	−0.9
18	36 11 S	95 23 E	−21.9	−20.1	−17 3	−21.2	−1.8	−4 6	−0.7
19	36 10 S	96 58 E	−21.0	−19.4	−16 7	−20.3	−1 6	−4.3	−0.7
19	35 56 S	97 34 E	−20.1	−18.8	−15.9	−19.6	−1.3	−4.2	−0.5
19	36 02 S	97 36 E	−19.7	−19.0	−16.1	−19.8	−0.7	−3.6	+0.1
20	37 12 S	97 28 E	−21.4	−20 3	−17.3	−21.1	−1.1	−4.1	−0.3
20	38 02 S	97 34 E	−22.2	−21.1	−18.2	−22.0	−1.1	−4.0	−0.2
21	39 22 S	98 28 E	−23.0	−21.9	−19.1	−22.9	−1 1	−3.9	−0.1
21	40 04 S	99 35 E	−23.7	−22.0	−19.3	−23.0	−1.7	−4.4	−0.7
22	41 48 S	100 18 E	−25.6	−24.2	−20 5	−24.5	−1.4	−5.1	−1.1
22	43 07 S	100 36 E	−26.2	−25.9	−21.9	−25.8	−0.3	−4.3	−0.4
23	46 48 S	101 43 E	−31.8	30.4	−25.5	−30.1	−1.4	−6.3	−1.7
24	47 39 S	101 58 E	−32.6	−31.2	−26.5	−31.1	−1.4	−6.1	−1.5

TABLE 2.—*Magnetic declinations and chart corrections observed on the Carnegie from Lyttelton, New Zealand, to South Georgia, thence to Lyttelton, Dec. 1915 to Apr. 1916*—cont.

Date.	Position.		Carnegie.	Chart values.			Chart corrections.		
	Lat.	Long.		Brit.	Ger.	U. S.	Brit.	Ger.	U. S.
1916	° ′	° ′	°	°	°	°	°	°	°
Feb. 24	47 58 S	102 04 E	−33.4	−31.4	−26.6	−31.5	−2.0	−6.8	−1.9
25	47 55 S	102 56 E	−33.0	−30.6	−26.1	−30.6	−2.4	−6.9	−2.4
25	47 51 S	104 08 E	−30.3	−29.7	−25.1	−29.9	−0.6	−5.2	−0.4
26	49 13 S	104 25 E	−33.7	−31.2	−26.6	−31.2	−2.5	−7.1	−2.5
26	50 35 S	105 19 E	−34.4	−32.2	−27.7	−32.3	−2.2	−6.7	−2.1
27	52 04 S	106 16 E	−36.5	−33.3	−28.9	−33.5	−3.2	−7.6	−3.0
27	53 03 S	107 02 E	−37.4	−34.0	−29.4	−33.9	−3.4	−8.0	−3.5
28	54 13 S	107 29 E	−40.4	−35.1	−30.3	−35.1	−5.3	−10.1	−5.3
29	57 10 S	108 17 E	−45.9	−37.7	−33.4	−37.5	−8.2	−12.5	−8.4
29	57 31 S	108 44 E	−45.4	−37.9	−33.4	−37.5	−7.5	−12.0	−7.9
Mar. 1	58 49 S	109 20 E	−49.6	−39.0	−34.9	−38.7	−10.6	−14.7	−10.9
1	58 59 S	109 36 E	−49.7	−39.1	−35.0	−38.8	−10.6	−14.7	−10.9
1	59 24 S	110 24 E	−50.6	−39.0	−34.6	−38.5	−11.6	−16.0	−12.1
1	59 17 S	110 51 E	−50.5	−38.5	−34.2	−38.0	−12.0	−16.3	−12.5
2	57 46 S	111 59 E	−44.5	−35.7	−31.4	−35.5	−8.8	−13.1	−9.0
2	56 18 S	112 33 E	−41.8	−33.2	−29.0	−33.0	−8.6	−12.8	−8.8
3	54 32 S	113 24 E	−36.2	−30.0	−25.8	−29.7	−6.2	−10.4	−6.5
3	53 25 S	113 51 E	−32.0	−28.2	−24.3	−28.0	−3.8	−7.7	−4.0
3	53 02 S	114 04 E	−31.2	−27.5	−23.4	−27.0	−3.7	−7.8	−4.2
4	51 34 S	115 56 E	−25.9	−23.5	−20.0	−23.5	−2.4	−5.9	−2.4
4	51 27 S	117 34 E	−23.2	−21.4	−18.5	−21.5	−1.8	−4.7	−1.7
5	49 43 S	119 50 E	−17.4	−16.9	−14.3	−16.6	−0.5	−3.1	−0.8
5	48 36 S	120 53 E	−14.9	−14.3	−11.7	−13.8	−0.6	−3.2	−1.1
6	46 46 S	122 28 E	−10.4	−10.2	−8.4	−9.6	−0.2	−2.0	−0.8
7	45 11 S	124 56 E	−6.1	−5.2	−5.0	−5.1	−0.9	−1.1	−1.0
8	45 00 S	125 53 E	−5.7	−4.4	−3.9	−4.4	−1.3	−1.8	−1.3
8	44 58 S	126 09 E	−5.0	−4.0	−3.6	−4.1	−1.0	−1.4	−0.9
9	44 44 S	126 23 E	−4.9	−3.7	−3.3	−3.8	−1.2	−1.6	−1.1
9	43 44 S	126 40 E	−4.0	−3.0	−2.6	−3.0	−1.0	−1.4	−1.0
10	42 05 S	127 36 E	−2.3	−1.4	−1.1	−1.5	−0.9	−1.2	−0.8
10	41 32 S	128 03 E	−0.8	−0.8	−0.5	−0.8	0.0	−0.3	0.0
11	40 26 S	128 59 E	−0.5	+0.2	+0.2	+0.3	−0.7	−0.7	−0.8
11	40 21 S	129 01 E	−0.4	+0.3	+0.3	+0.4	−0.7	−0.7	−0.8
11	39 39 S	129 28 E	+0.1	+0.6	+0.7	+0.7	−0.5	−0.6	−0.6
11	39 29 S	129 45 E	+0.3	+0.8	+1.0	+0.8	−0.5	−0.7	−0.5
12	39 57 S	129 57 E	+0.4	+0.8	+0.9	+0.7	−0.4	−0.5	−0.3
12	40 49 S	130 06 E	+0.1	+0.7	+0.8	+0.7	−0.6	−0.7	−0.6
12	41 01 S	130 08 E	+0.2	+0.7	+0.7	+0.6	−0.5	−0.5	−0.4
13	42 27 S	130 51 E	+0.2	+0.7	+0.6	+0.9	−0.5	−0.4	−0.7
13	43 50 S	130 55 E	−0.2	+0.3	+0.5	+0.4	−0.5	−0.7	−0.6
14	45 41 S	130 50 E	−0.7	−0.5	0.0	−0.1	−0.2	−0.7	−0.6
14	47 08 S	130 51 E	−1.2	−1.0	−0.9	−1.0	−0.2	−0.3	−0.2
15	48 24 S	132 19 E	−1.2	−0.2	−0.1	0.0	−1.0	−1.1	−1.2
15	49 09 S	132 50 E	−1.2	−0.1	0.0	0.0	−1.1	−1.2	−1.2
16	50 20 S	132 56 E	−1.8	−0.7	−0.5	−0.5	−1.1	−1.3	−1.3
16	51 00 S	132 42 E	−1.4	−1.2	−1.4	−1.1	−0.2	0.0	−0.3
17	53 13 S	132 02 E	−5.3	−3.7	−4.0	−3.8	−1.6	−1.3	−1.5
17	54 27 S	132 07 E	−6.7	−4.8	−5.1	−4.9	−1.9	−1.6	−1.8
17	54 37 S	132 08 E	−6.1	−5.0	−5.4	−5.0	−1.1	−0.7	−1.1
18	56 36 S	132 54 E	−8.9	−6.0	−6.2	−6.0	−2.9	−2.7	−2.9
18	56 37 S	133 27 E	−8.2	−5.2	−5.8	−5.2	−3.0	−2.4	−3.0
19	56 40 S	134 26 E	−7.9	−3.8	−4.8	−3.7	−4.1	−3.1	−4.2
19	57 13 S	135 50 E	−4.6	−2.4	−3.3	−2.0	−2.2	−1.3	−2.6
19	57 25 S	135 53 E	−5.3	−2.5	−3.4	−2.2	−2.8	−1.9	−3.1
20	57 08 S	137 54 E	−2.9	+0.9	0.0	+1.0	−3.8	−2.9	−3.9
20	57 12 S	139 10 E	+0.2	+2.5	+1.5	+2.6	−2.3	−1.3	−2.4

TABLE 2.—*Magnetic declinations and chart corrections observed on the Carnegie from Lyttelton New Zealand, to South Georgia, thence to Lyttelton, Dec. 1915 to Apr. 1916*—concluded.

Date.	Position.		Carnegie.	Chart values.			Chart corrections.		
	Lat.	Long.		Brit.	Ger.	U. S.	Brit.	Ger.	U. S.
1916	° ′	° ′	°	°	°	°	°	°	°
Mar. 21	56 57 S	142 07 E	+ 4.4	+ 6.7	+ 5.2	+ 6.4	−2.3	−0.8	−2.0
22	56 52 S	144 33 E	+ 6.8	+ 9.8	+ 7.6	+10.0	−3.0	−0.8	−3.2
23	56 41 S	146 57 E	+11.8	+11.8	+10.1	+11.6	0.0	+1.7	+0.2
24	54 35 S	150 40 E	+14.3	+13.7	+12.7	+13.7	+0.6	+1.6	+0.6
24	54 09 S	151 32 E	+13.8	+14.1	+13.2	+14.0	−0.3	+0.6	−0.2
25	53 07 S	153 50 E	+15.8	+15.2	+14.3	+15.0	+0.6	+1.5	+0.8
26	52 41 S	156 22 E	+16.0	+16.6	+16.1	+16.5	−0.6	−0.1	−0.5
27	51 26 S	159 54 E	+17.6	+18.3	+17.3	+18.2	−0.7	+0.3	−0.6
27	50 30 S	161 34 E	+17.7	+18.9	+17.7	+18.7	−1.2	0.0	−1.0
28	48 49 S	163 29 E	+17.4	+18.7	+17.7	+18.5	−1.3	−0.3	−1.1
28	48 27 S	164 44 E	+17.5	+18.6	+18.1	+18.7	−1.1	−0.6	−1.2
29	48 12 S	167 08 E	+17.8	+18.9	+18.7	+19.2	−1.1	−0.9	−1.4
29	47 13 S	169 15 E	+18.0	+18.4	+18.8	+18.8	−0.4	−0.8	−0.8
30	46 39 S	170 32 E	+18.3	+18.3	+18.9	+18.6	0.0	−0.6	−0.3
30	45 50 S	171 22 E	+17.8	+18.2	+18.7	+18.3	−0.4	−0.9	−0.5
31	44 59 S	172 31 E	+17.6	+17.9	+18.6	+18.0	−0.3	−1.0	−0.4
31	44 31 S	173 04 E	+17.4	+17.7	+18.3	+17.7	−0.3	−0.9	−0.3
Apr. 1	43 38 S	173 02 E	+17.2	+17.0	+17.8	+17.2	+0.2	−0.6	0.0

TABLE 3.—*Magnetic declinations and chart corrections observed on the Carnegie from Lyttelton New Zealand, to San Francisco, May–September 1916*[1].

Observers: J. P. Ault, commanding the *Carnegie;* H. M. W. Edmonds, I. A. Luke, F. C. Loring, B. Jones. *Minus sign indicates west declination; plus indicates east declination.*

Date.	Position.		Carnegie.	Chart values.			Chart corrections.		
	Lat.	Long.		Brit.[2]	Ger.[3]	U. S.[4]	Brit.	Ger.	U. S.
1916	° ′	° ′	°	°	°	°	°	°	°
May 10	43 32 S	172 48 E	+17.0	+17.1	+17.8	+17.2	−0.1	−0.8	−0.2
17	43 33 S	172 56 E	+16.3	+17.1	+17.8	+17.2	−0.8	−1.5	−0.9
18	43 41 S	174 07 E	+17.2	+17.1	+18.0	+17.3	+0.1	−0.8	−0.1
18	43 57 S	174 43 E	+17.2	+17.4	+18.2	+17.5	−0.2	−1.0	−0.3
19	43 07 S	174 19 E	+17.1	+17.0	+17.8	+17.0	+0.1	−0.7	+0.1
20	43 36 S	175 40 E	+17.2	+17.3	+17.9	+17.4	−0.1	−0.7	−0.2
21	43 59 S	176 34 E	+17.6	+17.7	+18.3	+17.7	−0.1	−0.7	−0.1
22	43 55 S	177 40 E	+17.6	+17.7	+18.2	+17.7	−0.1	−0.6	−0.1
22	44 14 S	179 08 E	+17.6	+17.8	+18.3	+17.8	−0.2	−0.7	−0.2
22[5]	43 57 S	178 36 W	+17.9	+17.5	+17.9	+17.5	+0.4	0.0	+0.4
22[5]	43 16 S	177 42 W	+17.4	+17.1	+17.5	+17.1	+0.3	−0.1	+0.3
23	41 47 S	175 55 W	+16.7	+16.3	+16.7	+16.4	+0.4	0.0	+0.3
23	40 50 S	175 24 W	+16.6	+16.1	+16.3	+16.1	+0.5	+0.3	+0.5
24	39 57 S	174 21 W	+16.7	+15.5	+15.9	+15.7	+1.2	+0.8	+1.0
24	39 42 S	174 13 W	+16.2	+15.5	+15.7	+15.7	+0.7	+0.5	+0.5
25	37 26 S	173 35 W	+15.7	+14.9	+14.9	+14.9	+0.8	+0.8	+0.8
25	37 13 S	173 32 W	+15.4	+14.9	+14.8	+14.9	+0.5	+0.6	+0.5

[1]For previous table, see footnote 1, Table 1.
[2]From British Admiralty Chart No. 2598 for 1912, referred to 1916.
[3]From Reichs-Marine-Amt Chart, Tit. XIV, No. 2, for 1910, referred to 1916 by means of the secular change given on U. S. Chart.
[4]From U. S. Hydrographic Office Chart No. 2406 for 1915, referred to 1916.
[5]Crossed 180th meridian, hence May 22 occurs twice.

TABLE 3.—*Magnetic declinations and chart corrections observed on the Carnegie from Lyttelton, New Zealand, to San Francisco, May–September 1916*—continued.

Date.	Position.		Carnegie.	Chart values.			Chart corrections.		
	Lat.	Long.		Brit.	Ger.	U. S.	Brit.	Ger.	U. S.
1916	° ′	° ′	°	°	°	°	°	°	°
May 25	35 59 S	172 59 W	+15 2	+14 7	+14 4	+14.7	+0.5	+0.8	+0.5
26	34 06 S	172 42 W	+14 2	+14 3	+13 8	+14.3	−0.1	+0.4	−0.1
26	33 04 S	172 42 W	+14 2	+14.1	+13.5	+14.1	+0.1	+0.7	+0.1
27	31 14 S	173 49 W	+13 5	+13 7	+13.1	+13.6	−0.2	+0.4	−0.1
28	30 59 S	173 58 W	+13 6	+13 6	+13.0	+13.5	0.0	+0.6	+0.1
29	30 36 S	172 15 W	+13 2	+13 5	+12.9	+13.3	−0.3	+0.3	−0.1
31	28 56 S	171 12 W	+13 1	+13 2	+12.5	+12.8	−0 1	+0.6	+0.3
31	28 41 S	170 06 W	+13 3	+13 3	+12 5	+12 8	0.0	+0 8	+0 5
June 1	27 19 S	168 30 W	+12 4	+12 7	+12 0	+12 5	−0.3	+0.4	−0 1
1	26 17 S	168 23 W	+12 2	+12 5	+11 8	+12.3	−0.3	+0.4	−0 1
2	24 57 S	168 19 W	+12 0	+12 1	+11 6	+11 9	−0 1	+0.4	+0 1
2	24 24 S	168 26 W	+11 8	+12 0	+11.5	+11 8	−0 2	+0 3	0.0
3	22 22 S	169 04 W	+11 5	+11 5	+11.1	+11 4	0 0	+0 4	+0 1
5	18 45 S	170 55 W	+10 7	+10.9	+10 5	+10 7	−0 2	+0.2	0 0
5	18 23 S	170 55 W	+10 4	+10 8	+10 4	+10 6	−0.4	0 0	−0 2
6	16 04 S	170 28 W	+ 9 8	+10 4	+10 0	+10.3	−0 6	−0 2	−0 5
7	14 37 S	170 27 W	+ 9.9	+10 1	+ 9 7	+10.0	−0 2	+0 2	−0.1
19	14 17 S	170 54 W	+10 1	+10 0	+ 9 5	+ 9 9	+0 1	+0 6	+0 2
20	12 32 S	171 02 W	+ 9 6	+ 9 8	+ 9 3	+ 9 7	−0.2	+0.3	−0.1
20	11 15 S	170 42 W	+ 9 4	+ 9 6	+ 9 1	+ 9 6	−0 2	+0 3	−0 2
21	9 34 S	170 32 W	+ 8 9	+ 9.4	+ 9 0	+ 9 4	−0 5	−0 1	−0 5
21	8 56 S	170 38 W	+ 8 8	+ 9 3	+ 8 9	+ 9 3	−0 5	−0 1	−0.5
22	7 15 S	170 54 W	+ 8 9	+ 9 2	+ 8 8	+ 9.2	−0.3	+0 1	−0 3
22	5 51 S	171 25 W	+ 8 6	+ 9 1	+ 8 7	+ 9 2	−0 5	−0 1	−0 6
23	4 19 S	171 59 W	+ 9 0	+ 9 0	+ 8 7	+ 9 2	0 0	+0 3	−0 2
23	3 02 S	172 14 W	+ 8 6	+ 9 0	+ 8 7	+ 9 2	−0 4	−0 1	−0 6
24	1 51 S	172 51 W	+ 8 4	+ 9 0	+ 8 7	+ 9 2	−0 6	−0 3	−0 8
24	0 55 S	173 15 W	+ 8 5	+ 9 0	+ 8 7	+ 9 0	−0.5	−0 2	−0 5
25	0 17 N	173 49 W	+ 8 7	+ 9 1	+ 8 8	+ 9.0	−0 4	−0 1	−0 3
25	0 52 N	174 02 W	+ 8 6	+ 9 1	+ 8 9	+ 9 0	−0 5	−0 3	−0 4
26	1 42 N	174 55 W	+ 8 6	+ 9 2	+ 8 9	+ 9 0	−0 6	−0 3	−0 4
26	2 40 N	175 50 W	+ 8 3	+ 9 2	+ 9 0	+ 9 0	−0 9	−0 7	−0.7
27	3 54 N	176 48 W	+ 9 2	+ 9 2	+ 9 2	+ 9 0	0 0	0 0	+0 2
27	5 10 N	177 23 W	+ 8 9	+ 9 2	+ 9 3	+ 9 0	−0 3	−0 4	−0 1
28	6 48 N	178 04 W	+ 8 8	+ 9 2	+ 9 4	+ 9.0	−0 4	−0 6	−0.2
28	8 15 N	178 38 W	+ 9 0	+ 9.5	+ 9 6	+ 9 1	−0.5	−0 6	−0.1
29	9 49 N	179 20 W	+ 9 2	+ 9 5	+ 9 7	+ 9 1	−0 3	−0.5	+0.1
29	11 11 N	179 50 E	+ 9 4	+ 9 5	+ 9 8	+ 9 2	−0 1	−0 4	+0 2
July 1[1]	12 44 N	179 13 E	+ 9 1	+ 9.5	+ 9.8	+ 9 2	−0.4	−0.7	−0 1
1	13 17 N	178 52 E	+ 8 4	+ 9.5	+ 9 8	+ 9.2	−1.1	−1.4	−0 8
2	14 29 N	177 36 E	+ 9.1	+ 9.4	+ 9 7	+ 9 1	−0 3	−0.6	0 0
2	15 03 N	176 23 E	+ 9 0	+ 9.3	+ 9 6	+ 9 0	−0.3	−0.6	0.0
3	15 35 N	174 39 E	+ 9 0	+ 9.1	+ 9.3	+ 8 7	−0 1	−0.3	+0 3
4	16 04 N	172 48 E	+ 8.6	+ 8.7	+ 8 9	+ 8 4	−0.1	−0 3	+0.2
4	16 36 N	171 37 E	+ 8 1	+ 8.5	+ 8.7	+ 8.2	−0.4	−0.6	−0.1
5	17 06 N	170 37 E	+ 8 0	+ 8.3	+ 8.5	+ 8.0	−0.3	−0.5	0.0
5	17 37 N	169 32 E	+ 7 5	+ 8.1	+ 8.2	+ 7 7	−0.6	−0.7	−0.2
6	18 06 N	167 59 E	+ 7 3	+ 7.7	+ 7.7	+ 7.3	−0.4	−0.4	0.0
6	18 33 N	167 01 E	+ 6 7	+ 7 4	+ 7 4	+ 7.0	−0.7	−0.7	−0.3
7	19 12 N	165 46 E	+ 6.5	+ 7.1	+ 7.1	+ 6.6	−0.6	−0.6	−0.1
7	19 41 N	164 41 E	+ 6 7	+ 6 8	+ 6 6	+ 6.3	−0.1	+0.1	+0.4
8	20 17 N	163 30 E	+ 6 0	+ 6 3	+ 6.2	+ 5.9	−0.3	−0.2	+0.1
8	20 22 N	162 36 E	+ 5.2	+ 6 0	+ 6.0	+ 5.6	−0.8	−0.8	−0.4
9	20 31 N	161 44 E	+ 4.9	+ 5.8	+ 5.7	+ 5.4	−0.9	−0.8	−0.5
9	20 24 N	160 43 E	+ 4 8	+ 5.5	+ 5.1	+ 5.2	−0.7	−0.3	−0.4
10	20 07 N	159 56 E	+ 4.4	+ 5.4	+ 5 1	+ 5.0	−1.0	−0.7	−0.6

[1]Crossed 180th meridian, omitting the date June 30.

TABLE 3.—*Magnetic declinations and chart corrections observed on the Carnegie from Lyttelton, New Zealand, to San Francisco, May–September, 1916*—continued.

Date.	Position.		Carnegie.	Chart values.			Chart corrections.		
	Lat.	Long.		Brit.	Ger.	U. S.	Brit.	Ger.	U. S.
1916	° ′	° ′	°	°	°	°	°	°	°
July 10	19 49 N	158 59 E	+4.1	+5.2	+4.9	+4.8	−1.1	−0.8	−0.7
11	19 29 N	158 05 E	+4.1	+5.0	+4.8	+4.6	−0.9	−0.7	−0.5
11	19 08 N	157 11 E	+3.7	+4.8	+4.5	+4.3	−1.1	−0.8	−0.6
12	18 28 N	155 51 E	+3.6	+4.4	+4.2	+4.1	−0.8	−0.6	−0.5
12	17 55 N	154 44 E	+3.2	+4.2	+4.0	+3.8	−1.0	−0.8	−0.6
13	17 20 N	153 29 E	+3.0	+4.0	+3.7	+3.6	−1.0	−0.7	−0.6
13	16 50 N	152 23 E	+3.2	+3.7	+3.5	+3.3	−0.5	−0.3	−0.1
14	16 13 N	151 10 E	+2.7	+3.6	+3.3	+3.2	−0.9	−0.6	−0.5
14	15 39 N	150 07 E	+2.5	+3.4	+3.1	+3.0	−0.9	−0.6	−0.5
15	14 54 N	148 41 E	+2.5	+3.3	+2.9	+2.9	−0.8	−0.4	−0.4
15	14 32 N	147 32 E	+2.2	+3.1	+2.7	+2.6	−0.9	−0.5	−0.4
16	13 54 N	145 38 E	+1.9	+2.8	+2.3	+2.4	−0.9	−0.4	−0.5
16	13 52 N	145 30 E	+2.1	+2.8	+2.3	+2.3	−0.7	−0.2	−0.2
17	13 35 N	144 39 E	+2.1	+2.7	+2.2	+2.2	−0.6	−0.1	−0.1
Aug. 8	14 38 N	144 25 E	+1.3	+2.6	+2.0	+1.9	−1.3	−0.7	−0.6
10	17 26 N	144 33 E	+0.7	+2.0	+1.4	+1.4	−1.3	−0.7	−0.7
11	18 10 N	144 14 E	+0.8	+1.7	+1.1	+1.2	−0.9	−0.3	−0.4
12	19 12 N	143 36 E	+0.7	+1.2	+0.8	+0.8	−0.5	−0.1	−0.1
13	23 03 N	144 27 E	−0.5	+0.4	0.0	−0.2	−0.9	−0.5	−0.3
14	26 29 N	144 35 E	−1.6	−0.8	−1.0	−1.4	−0.8	−0.6	−0.2
14	26 34 N	144 34 E	−1.6	−0.8	−1.0	−1.5	−0.8	−0.6	−0.1
14	27 38 N	144 14 E	−2.0	−1.2	−1.2	−2.0	−0.8	−0.8	0.0
15	29 32 N	144 07 E	−2.7	−1.8	−1.8	−2.5	−0.9	−0.9	−0.2
15	30 14 N	144 06 E	−2.7	−2.1	−2.1	−2.7	−0.6	−0.6	0.0
16	30 14 N	144 27 E	−2.7	−2.0	−2.0	−2.6	−0.7	−0.7	−0.1
16	30 34 N	144 07 E	−3.0	−2.2	−2.2	−2.8	−0.8	−0.8	−0.2
17	31 49 N	143 31 E	−3.3	−2.7	−2.8	−3.2	−0.6	−0.5	−0.1
19	36 12 N	149 58 E	−3.3	−2.4	−2.0	−3.0	−0.9	−1.3	−0.3
20	38 17 N	153 31 E	−2.7	−1.8	−1.4	−2.4	−0.9	−1.3	−0.3
20	38 25 N	153 43 E	−2.4	−1.8	−1.3	−2.3	−0.6	−1.1	−0.1
21	40 11 N	156 28 E	−1.9	−1.1	−1.0	−1.5	−0.8	−0.9	−0.4
22	42 41 N	158 15 E	−1.7	−0.9	−0.8	−1.2	−0.8	−0.9	−0.5
22	43 13 N	158 40 E	−1.5	−0.9	−0.8	−1.0	−0.6	−0.7	−0.5
23	44 24 N	158 59 E	−1.5	−1.0	−0.9	−1.1	−0.5	−0.6	−0.4
23	45 21 N	159 32 E	−1.7	−1.0	−0.8	−1.1	−0.7	−0.9	−0.6
24	46 20 N	160 12 E	−1.3	−0.8	−0.5	−0.9	−0.5	−0.8	−0.4
25	46 54 N	162 58 E	−0.5	+0.2	+0.6	+0.4	−0.7	−1.1	−0.9
25	46 57 N	163 27 E	−0.1	+0.4	+0.9	+0.7	−0.5	−1.0	−0.8
26	47 03 N	165 21 E	+0.3	+1.1	+1.6	+1.4	−0.8	−1.3	−1.1
27	47 14 N	166 54 E	+1.8	+1.7	+2.2	+2.2	+0.1	−0.4	−0.4
27[1]	47 15 N	167 13 E	+1.7	+2.0	+2.4	+2.4	−0.3	−0.7	−0.7
27	47 20 N	168 10 E	+2.3	+2.6	+2.8	+2.8	−0.3	−0.5	−0.5
28	47 25 N	169 02 E	+1.8	+3.0	+3.2	+3.2	−1.2	−1.4	−1.4
28	47 28 N	169 40 E	+3.3	+3.4	+3.5	+3.5	−0.1	−0.2	−0.2
29	47 46 N	172 03 E	+4.0	+4.6	+4.5	+4.7	−0.6	−0.5	−0.7
30	48 09 N	174 24 E	+5.4	+5.7	+5.6	+5.8	−0.3	−0.2	−0.4
30[2]	49 00 N	179 37 W	+8.5	+8.7	+8.8	+8.8	−0.2	−0.3	−0.3
31	49 34 N	177 13 W	+10.1	+10.0	+9.9	+9.8	+0.1	+0.2	+0.3
Sept. 1	49 58 N	175 23 W	+11.1	+11.0	+10.9	+10.7	+0.1	+0.2	+0.4
2	50 46 N	173 04 W	+12.1	+12.2	+12.2	+12.0	−0.1	−0.1	+0.1
3	51 22 N	168 56 W	+14.3	+14.6	+14.2	+14.5	−0.3	+0.1	−0.2
3	51 38 N	167 07 W	+15.4	+15.5	+15.2	+15.5	−0.1	+0.2	−0.1
4	51 55 N	164 26 W	+16.6	+16.8	+16.5	+16.9	−0.2	+0.1	−0.3
5	52 28 N	161 21 W	+17.9	+18.2	+17.8	+18.2	−0.3	+0.1	−0.3
5	52 47 N	159 46 W	+18.7	+18.8	+18.7	+18.8	−0.1	0.0	−0.1

[1]Ship was swung during observations.
[2]Crossed 180th meridian, repeating the date August 30, 1916.

TABLE 3.—*Magnetic declination and chart corrections observed on the Carnegie from Lyttelton, New Zealand, to San Francisco, May–September, 1916*—concluded.

Date.	Position.		Carnegie.	Chart values.			Chart corrections.		
	Lat.	Long.		Brit.	Ger.	U. S.	Brit.	Ger.	U. S.
1916	° ′	° ′	°	°	°	°	°	°	°
Sept. 6	53 22 N	156 29 W	+20.4	+20.4	+20.2	+20.2	0.0	+0.2	+0.2
7	52 57 N	151 50 W	+21.9	+21.9	+22.0	+21.9	0.0	−0.1	0.0
8	51 16 N	146 46 W	+22.2	+22.7	+23.0	+23.0	−0.5	−0.8	−0.8
9	49 49 N	144 32 W	+23.3	+22.6	+22.9	+22.8	+0.7	+0.4	+0.5
10	47 42 N	141 45 W	+22.7	+22.1	+22.6	+22.4	+0.6	+0.1	+0.3
10	46 49 N	140 51 W	+22.5	+21.9	+22.2	+22.3	+0.6	+0.3	+0.2
11	45 37 N	139 32 W	+21.9	+21.4	+21.7	+21.8	+0.5	+0.2	+0.1
11	45 26 N	139 21 W	+21.3	+21.3	+21.7	+21.8	0.0	−0.4	−0.5
12	43 44 N	138 25 W	+20.9	+20.4	+20.7	+21.2	+0.5	+0.2	−0.3
12	42 26 N	138 11 W	+20.1	+19.8	+20.2	+20.5	+0.3	−0.1	−0.4
13	41 42 N	138 17 W	+20.2	+19.4	+19.7	+20.1	+0.8	+0.5	+0.1
14	40 51 N	138 14 W	+19.7	+18.9	+19.3	+19.7	+0.8	+0.4	0.0
15	40 48 N	138 06 W	+19.9	+18.9	+19.2	+19.7	+1.0	+0.7	+0.2
15	40 47 N	137 33 W	+19.5	+19.0	+19.2	+19.7	+0.5	+0.3	−0.2
16	40 41 N	135 56 W	+19.8	+19.1	+19.3	+19.8	+0.7	+0.5	0.0
16	40 38 N	134 22 W	+19.2	+19.2	+19.4	+20.0	0.0	−0.2	−0.8
17	40 23 N	132 00 W	+19.8	+19.2	+19.3	+19.9	+0.6	+0.5	−0.1
17	39 56 N	130 33 W	+19.6	+19.2	+19.1	+19.6	+0.4	+0.5	0.0
18	39 41 N	129 55 W	+19.5	+19.1	+19.0	+19.5	+0.4	+0.5	0.0
21	37 46 N	122 35 W	+18.8	+18.5	+17.9	+18.1	+0.3	+0.9	+0.7

LAND WORK.

AFRICA.

Observer H. E. Sawyer arrived at Durban, Natal, South Africa, on March 20, 1916, to take up magnetic-survey work in Africa, having been relieved of ocean duty after the *Carnegie's* arrival at Lyttelton from Dutch Harbor (see page 316). From Durban he continued to Cape Town by rail, observing at 4 stations, including Durban, and arriving at Cape Town April 4. From Cape Town a trip was made to Walfish Bay, German Southwest Africa, by steamer, thence return to Cape Town by rail, observing at 7 stations along the railroad. At Cape Town intercomparison-observations were made with the instruments used by Dr. J. C. Beattie, of South African College. On May 18, Mr. Sawyer left Cape Town by steamer for Boma, Belgian Kongo, making observations at 3 coast stations en route. From Boma he proceeded to Brazzaville and thence overland to Libreville, French Kongo. The work in Central Africa will depend on the conditions encountered; the endeavor will be to undertake an expedition by the most feasible route to Lake Tchad.

ASIA.

The magnetic-survey work in Asia has been carried out entirely in China, under the direction of Dr. C. K. Edmunds, assisted by Observer F. Brown. On November 1, 1915, Dr. Edmunds was in Shansi Province, traveling by cart and mule-back westward from Peking

towards the Yellow River. He arrived at Paotehchow, on the Yellow River, November 15. Here the river was crossed into Shensi Province, and a southerly route followed overland to Sianfu, and thence southwest to Sungpan, Szechwan, and south to Chengtu, arriving at the latter place March 2, 1916. From here the survey was extended westward as far as Yachowfu, the party thence proceeding overland eastward to Chungking, on the Yangtse, via Kiatingfu. From Chungking it was possible to go by boat down the Yangtse River, thus giving the observer some respite from the continuous travel by cart and mule-back during the preceding 5 months. Hankow was reached May 6, and thence Dr. Edmunds proceeded direct to Canton, via Nanking and Shanghai, arriving at Canton May 19. After attending to various affairs and duties at the Canton Christian College, of which Dr. Edmunds is president, he left for Peking, meeting Mr. Brown there on June 8.

The balance of June 1916 was spent at Peking, Tientsin, and Pehtaiho attending to correspondence, completion of observation-records, and consideration of plans for the future work by both Dr. Edmunds and Mr. Brown. From Peking Dr. Edmunds proceeded west to the Yellow River, thence south and southeast to Hankow, there closing his work in connection with the general magnetic survey of China about the middle of September 1916 and returning to Canton. During the work as outlined to the west from Peking, Dr. Edmunds was accompanied by Mr. H. J. Fairburn as interpreter-companion.

On November 1, 1915, Mr. Brown was at Urga, Mongolia, completing the necessary arrangements for the trip southward towards Lanchowfu. He left Urga on November 11, and traveled by camel caravan approximately in a southwesterly direction to longitude 101° E. and latitude 45° N. Thence he proceeded southward to Liangchowfu via Tingyüanying. In about longitude 104°.5 E. and latitude 40° N., Mr. Brown heard of a route to Liangchowfu via Chenfan; accordingly, leaving the road, he struck southwest with his party across country, getting into a desert of rocky hills and high ranges of absolutely smooth sandhills, but finally emerging on the Kalgan-Kanchow road, and reaching Liangchowfu safely on January 20, 1916. Thence the trip was continued towards Lanchowfu via Siningfu. From Lanchowfu the valley of the Yellow River was followed northeast and east to Kweihwating, the party traveling by camel caravan to Paotowchen, May 16, 1916, and thereafter by horse and cart to May 29, when the railroad was reached at Fengchen, and proceeding by rail to Kalgan and thence to Peking, joining Dr. Edmunds at the latter place on June 8, 1916.

At Peking a program for the rest of the year was arranged as far as the uncertain political conditions permitted. It was decided that Mr. Brown should devote the months of July, August, and September,

to observing throughout Manchuria at points on the various railway lines. Upon concluding this work, he was to proceed to Chungking and undertake, if conditions permitted, an extended expedition across Yunnan into Kwangsi Province. Before setting out on his Manchuria campaign, Mr. Brown established new stations at Peking and Tientsin, observed at Lwanchow, Pehtaiho, and Funinghsien, and reoccupied Shanhaikwan in Chihli Province. At the end of August he had occupied 21 stations in Manchuria, 2 of which were repeat stations.

During this period Dr. Edmunds traversed northern Shansi westward from Tatungfu to Hokow on the Yellow River, which he descended to Tungkwanting and thence traveled overland southward to the basin of the Han River, and down the latter to Hankow, where he arrived on September 9. From Hankow he proceeded direct to Peking, thence to Tientsin and Pehtaiho, where he expected to meet Mr. Brown early in October and arrange for the campaign in western China. During this trip 19 magnetic stations were occupied.

AUSTRALASIA.

Observer W. C. Parkinson left Sydney, Australia, on October 13, 1915, and during the period October 13 to December 24, 1915, established a series of magnetic stations along the coast of British New Guinea and the outlying islands to the eastward, also occupying a station at Rabaul, New Britain. He returned to Sydney on December 24, and after securing at the Red Hill Observatory a series of intercomparisons with Observer H. E. Sawyer's instruments and attending to various official matters, he left for Lyttelton, New Zealand, on February 17, 1916. In consultation with Professor C. C. Farr, of Canterbury College, and Mr. H. F. Skey, director of the Christchurch Magnetic Observatory, a program of 11 stations in New Zealand was arranged for and carried out during March and April. During April and May Mr. Parkinson assisted Captain Ault in the work of the *Carnegie* at Lyttelton, New Zealand, besides completing the computations of his own observations. On May 10, 1916, Mr. Parkinson left Lyttelton for Perth, Western Australia, taking a short vacation en route at Sydney. He arrived in Perth on June 8, and took up the work in connection with the examination of suitable sites in southwestern Australia for the Department's proposed magnetic observatory. On August 2, 1916, Magnetician W. F. Wallis arrived at Perth, and since that date Mr. Parkinson has been a member of his observatory party. As the result of examinations of various sites, a location for the magnetic observatory was chosen by Mr. Wallis near Marchagee, about 150 miles north of Perth, Australia.

Observer H. E. Sawyer was detached from sea duty aboard the *Carnegie* at Lyttelton, New Zealand, on December 6, 1915, in order to

take up land-survey work in Africa. During December he occupied stations at New Brighton and Cass, and made intercomparison observations at the Christchurch Magnetic Observatory, New Zealand. Mr. Sawyer took a short vacation between December 25, 1915, and January 5, 1916, and then sailed on January 6 from Wellington for Sydney, Australia. At Sydney he secured at the Red Hill Observatory an intercomparison of instruments with those of Observer W. C. Parkinson. On February 19, Mr. Sawyer had completed all arrangements necessary at Sydney and sailed for Durban, South Africa (see page 314).

SOUTH AMERICA.

On September 30, 1916, Observers D. M. Wise and A. Sterling left New York bound for South America via the Panama Canal. After reoccupying, en route, our magnetic stations at Havana and Colon, the party made magnetic observations at various stations in Ecuador. The purpose of this trip, in addition to securing magnetic observations at points in various countries of South America, is to determine a suitable location for a magnetic observatory. The party is in charge of Mr. Wise.

MISCELLANEOUS WORK.

On May 17, 1916, Observer H. F. Johnston was relieved of ocean work aboard the *Carnegie* at Lyttelton, New Zealand. He proceeded to the island of Tahiti, where he made the observations required for the examination of the island as to a suitable site for a possible magnetic observatory; magnetic observations were made at 10 stations on the island of Tahiti and on the outlying coral islets. The region was found, in general, to be subject to local magnetic disturbance. Mr. Johnston sailed for San Francisco on July 2, 1916, and on arrival there reoccupied the magnetic stations of the Department at Goat Island and San Rafael, as also at San Diego. He reported at the office in Washington on August 7, 1916.

Special attention has been paid during the past year to securing additional comparisons between the magnetic standards of various services and ours and to the adequate control of instrumental constants. Besides frequent intercomparisons of our own instruments, both at Washington and in the field, the following comparisons with the standards of foreign observatories have been obtained since August 1915: (1) In Great Britain by E. Kidson, at Kew, Greenwich, Stonyhurst, and Eskdalemuir, August to October 1915; (2) at Washington during November and December 1915, with the standards of the Dominion Astronomical Observatory of Canada (Observer C. A. French) and with those of the Canadian Meteorological Service (Observer W. E. W. Jackson); (3) at Christchurch Magnetic Observatory by the *Carnegie* observing party in November 1915, and again in April–May 1916.

These comparisons have given additional data for the correlation of magnetic observations made by the various magnetic services.

Special observations for 5 magnetometers were made at Washington under Mr. Fleming's supervision, to determine with greater accuracy the moments of inertia of magnets with their suspension arrangements, 2 to 4 inertia bars being used for each instrument. The results show desired improvement. To obtain satisfactory values it was found necessary to make not less than 12 determinations of the moment of inertia with each inertia bar. In general the results of these investigations indicate that, when magnets and stirrups are carefully protected against oxidation and wear, as is the case of the Department's instruments, there is little or no change in the moments of inertia during field-work. The one notable exception was magnetometer 19, for which the observations indicate clearly a time-linear decrease between June 1912 and February 1916, of about 0.3 per cent in the moment of inertia. The linear change with time is confirmed by the excellent agreement in the corrections on International Magnetic Standard, determined on different dates at Washington, preceding and following the field-work, when corrections for the change were applied.

The investigations of possible changes in the values of the distribution coefficients for different instruments were continued. In general, although the accidental errors of determination are large, the indications are that the coefficients may be considered practically constant while the instruments are in active use, certainly for periods as long as 2 or 3 years. It is found that, in spite of utmost care used in making magnets, the coefficients do not agree with theoretical values derived from the formulæ involving the relative dimensions of long and short magnets. The various underlying causes for the discrepancies are under investigation.

ABSTRACTS OF PUBLICATIONS AND CONTRIBUTIONS TO SCIENTIFIC SOCIETIES.

List of publications of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington July 1, 1916. 8°, pp. 16.

This is the first complete list of publications and contributions to scientific societies by members and associates of the Department of Terrestrial Magnetism, from the year (1904) of the establishment of the Department to July 1, 1916. It is divided into three parts: (A) Papers and Contributions to Scientific Societies 1904–1916, 176 titles; (B) Annual Reports of the Director of the Department of Terrestrial Magnetism, 1904–1915, 12 titles; and (C) Major Publications, 1912–1916, 3 titles. It is proposed to issue a second edition early in 1917, in order to make the list complete to the end of 1916. Cross-references and brief explanatory remarks are added to the various titles, whenever necessary, for facilitating the use of the list.

Magnetic declinations and chart corrections obtained by the *Carnegie* from Dutch Harbor, Alaska, to Lyttelton, New Zeland, August–November 1915 J. P. Ault. Terr. Mag., vol. 21, 15–18 (Mar. 1916). Washington.

Cruise of the *Carnegie* from Lyttelton, New Zealand, to South Georgia, December 6, 1915, to January 12, 1916. J. P. Ault. Terr. Mag., vol. 21, 26–27 (Mar. 1916). Washington.

Cruise of the *Carnegie* from South Georgia to Lyttelton, New Zealand, January 14 to April 1, 1916. J. P. Ault. Terr. Mag., vol. 21, 103–106 (June 1916). Washington.

Magnetic declinations and chart corrections observed on the *Carnegie* from Lyttelton, New Zealand, to South Georgia, and thence to Lyttelton and Pago Pago, December 1915–June 1916. J. P. Ault. Terr. Mag., vol. 21, 109–116 (Sept. 1916). Washington.

These four papers by J. P. Ault, in command of the *Carnegie*, pertain to observations made aboard the vessel, 1915–16, and to experiences encountered on a circumnavigation voyage in the sub-Antarctic regions, December 6, 1915, to April 1, 1916. (See pages 297–314.)

Status of magnetic surveys in South America by the Carnegie Institution of Washington. L. A. Bauer. (Abstract of paper presented before Section II, Second Pan-American Scientific Congress at Washington, December 28, 1915; printed by the Congress.)

In response to the invitation received through the secretary-general of the Second Pan American Congress, the author presented before Section II of the Congress a summary of the work of the chief magnetic surveys conducted in South America, chiefly during 1908 to 1915, by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. Ten separate expeditions have been sent out, the stations at which the magnetic observations were made numbering 493. About 10 per cent of this number are repeat stations; that is, stations at which observations have been made in various years, either by others or by the Department of Terrestrial Magnetism. Thus, magnetic data for determining both the distribution of the magnetic elements, and their changes from time to time are obtained.

Every country in South America is represented in the list of stations, though the number of stations in the different countries varies considerably. Thanks to the very cordial cooperation being received from every organization in South America engaged in securing magnetic data, it has been possible to carry out effectively the published plan. This plan is not to duplicate but to supplement the work being done well by other organizations, so as to complete in the most expeditious manner possible the task of a general magnetic survey of the Earth.

The magnetic stations of the Carnegie Institution of Washington are densest in countries of South America not possessing a magnetic service. In the two countries, Argentina and Brazil, which are actively carrying on magnetic surveys, the Institution's work could be restricted in extent.

A special point, however, has been made of obtaining, at various times, comparisons of the Institution's magnetic standards with those of the other countries. In this way it has become possible to reduce all the recent magnetic data in South America to the same set of standards, with a degree of accuracy sufficient for both theoretical and practical purposes.

Some of the Institution's magnetic expeditions have been geographic achievements as well as contributions to the advancement of knowledge of the Earth's magnetism. In addition to the three magnetic elements (the magnetic declination, the magnetic inclination, and the intensity of the magnetic force), the parties obtain the geographic position of their stations with an accuracy commensurate with the purpose, as well as general geographic information.

A brief synopsis of the chief expeditions, 1908 to 1915, was given. The results and descriptions of stations up to 1913, inclusive, have been published in two volumes, issued by the Carnegie Institution of Washington.[1] The subsequent data are now being reduced, and it is hoped the volume to contain them can appear in 1917.

The next step will be to refer all the observations to the same date by means of the data obtained at the repeat stations and at the magnetic observvatories, of which, alas, there are too few in South America. Argentina and Brazil are the only countries at present in which such observatories are being maintained.

The construction of new magnetic charts for the entire globe, as based upon the data accumulated since 1905, is in progress.

Throughout the entire work in South America every assistance possible has been rendered in the furtherance of the Institution's magnetic work by the various South American Governments, and by private individuals who became interested in the work of the Department of Terrestrial Magnetism. For this invaluable cooperation, grateful acknowledgment is here made.

Concomitant changes in terrestrial magnetism and solar radiation. L. A. Bauer. Proc. Nat. Acad. Sci., vol. 2, 24–27 (Jan. 1916). Washington.

An abstract of a paper presented before the National Academy of Sciences at the New York meeting, November 17, 1915 (see abstract, "Solar radiation and terrestrial magnetism," page 330, Annual Report for 1915 published in Year Book No. 14).

Corresponding changes in the Earth's magnetic field and the solar radiation. L. A. Bauer. (Presented before the Philosophical Society of Washington, January 22, 1916.)

Investigations with the aid of more recent solar and magnetic data have confirmed the author's preliminary conclusions of 1914 and 1915.[2] It is again found in the majority of cases (about 80 per cent), that increased intensity of solar radiation, as shown by changes in solar-constant values possessing the accuracy of those of the Smithsonian Institution, is accompanied by an appreciable decrease in the constant used as a measure of the intensity of the Earth's magnetic field. While the magnetic effect, observed on the average, is such as accompanies the heating of a magnet, it is, apparently, not to be referred to such a cause. A preliminary examination of the magnetic effects in different parts of the Earth indicates that the seat of the system of forces causing the effects is not within the Earth itself, but in the regions above us.

In conclusion, it was pointed out that, from the standpoint of terrestrial magnetism, observations dependent solely upon the thermal energy of solar radiation can not be given any greater significance than that they may indicate some change in solar activity. Thus changes in the solar constant may not be regarded as a true or adequate measure of the various ionizing agencies (ultra-violet light, corpuscular radiations, electrons impinging upon our atmosphere, etc.) which are, at present, believed to be ultimately the cause of the magnetic effects. To the pyrheliometer, the bolometer, and meteorological appliances, must be added the magnetic needle, if we wish to get as complete a representation as possible of the many and different effects attributable to our Sun, directly or indirectly.

[1] Land Magnetic Observations, 1905–1910, by L. A. Bauer; Land Magnetic Observations, 1911–1913, and Reports on Special Researches, by L. A. Bauer and J. A. Fleming.
[2] Published in *Terr. Mag.*, vol. 19, 119–124, 1915, and vol. 20, 143–158, 1916.

On possible planetary magnetic effects. L. A. Bauer. Physical Rev., ser. 2, vol. 7, 500 (April 1916). Lancaster, Pa. (Abstract of paper presented at the New York meeting of the American Physical Society on February 26, 1916.)

The question of the existence of cosmical effects arising from possible planetary magnetic fields is engaging the attention of various investigators, especially of astronomers. For example, it has been known for 30 years or more that there are certain irregularities in the motions of the Moon too large to be accounted for by any possible outstanding gravitation effects. Similar irregularities are shown by the motions of Mercury, Venus, and the Earth. It therefore becomes a matter of interest to ascertain, if possible, whether these irregularities in the motions of astronomical bodies can be associated, in any way, with magnetic effects. Accordingly, as a first step, a formula has been theoretically established for determining the field strength of possible magnetic fields enveloping the members of our solar system for which certain requisite constants are known.

Let M_e represent the strength of the Earth's magnetic field at its poles, namely, about 0.65 of a C. G. S. unit, and let ω_e, r_e, d_e, g_e represent, respectively, the Earth's angular velocity of rotation, mean radius, mean density, and gravity at the surface. Give similar significance to the quantities M_a, ω_a, r_a, d_a, g_a for any rotating astronomical body (a). Then we may have approximately: $M_a : M_e = (\omega_a\, r_a^2\, d_a) : (\omega_e\, r_e^2\, d_e) = (\omega_a\, r_a\, g_a) : (\omega_e\, r_e\, g_e)$. If, for example, the astronomical body (a) is the Sun (S), there is obtained a field strength (M_s), for the Sun's possible period of rotation as a whole, which agrees within about 10 per cent of Hale's provisional value ($80M_s$). For the planets Mars, Jupiter, and Saturn, whose angular velocity of rotation is known, we get: $M_m = 0.2\ M_e$; $M_j = 68\ M_e$; $M_s = 24 M_e$. It thus appears that, on the hypothesis made, Jupiter, Saturn, and probably also Uranus and Neptune, may be enveloped by stronger magnetic fields than is the Earth. Jupiter's field may even approach in strength that of the Sun. In conclusion, the possible bearing was pointed out on the vexed outstanding question as to the precise cosmic conditions which determine the period and direction of rotation of a member of the solar system. (See pp. 291–292.)

The work done by the United States Coast and Geodetic Survey in the field of terrestrial magnetism. L. A. Bauer. Published in "Centennial Celebration of the United States Coast and Geodetic Survey," 1916, Washington. (One of the addresses in connection with the Centennial Exercises of the United States Coast and Geodetic Survey, April 5 and 6, 1916.)

In 1856 the number of stations at which the magnetic elements had been determined in the United States was about 160, distributed chiefly along the sea-coast. That was the status of the magnetic work of the Coast Survey six decades ago. At the close of 1915 the stations at which the magnetic elements have been completely determined by the survey number, in the United States proper, about 5,000, and about 500 in the outlying possessions. They are now found to be more regularly distributed over the large regions covered. About 80 per cent of the total number of stations have been occupied during the period 1899 to 1915 and at about 10 per cent the observations have been repeated, from time to time, in order to determine the changes ever going on in the Earth's magnetism. In addition, magnetic data at sea have been accumulated, as opportunity afforded, on cruises of Coast Survey vessels; a number of magnetic observatories (5 at present), where the countless fluctuations of the Earth's magnetism are being continuously recorded, have been operated; invaluable compilations of all available magnetic data in the United States and contiguous countries have been made; the instru-

ments used have been improved from time to time; about 150 magnetic publications and a large number of magnetic charts of various kinds have been issued.[1] It may, therefore, be said that the contributions of the Coast and Geodetic Survey to the advancement of our knowledge in terrestrial magnetism have been unexcelled by any other national organization.

From the earliest days of the Survey, magnetic observations were considered a legitimate and useful part of its work. In 1899 an enlarged annual appropriation of $25,000 (about ten times the average annual amount previously allotted), made it possible to carry out a magnetic survey of the whole United States on a more systematic basis and with greater expedition than had theretofore been possible. The plan adopted for the reorganized magnetic work of the Survey, on the basis of which the increased appropriation was made, was that submitted by L. A. Bauer in March 1899, at the request of the then Superintendent, H. S. Pritchett, who established on May 1, 1899, a new division, known as the Division of Terrestrial Magnetism. The chiefs of this Division have been: L. A. Bauer, 1899–1906; R. L. Faris, 1906–1915; and A. Braid, 1915–16. The present chief is D. L. Hazard, who was connected with the Division as computer from the date of its establishment. During the period 1900 to 1903, five magnetic observatories were established, in connection with which effective and skillful aid was rendered by J. A. Fleming, then aid in the Survey, now a member of the Department of Terrestrial Magnetism.

The year 1903 marks the inauguration of systematic magnetic observations at sea on the Survey vessels. During a trip made by L. A. Bauer, as inspector of magnetic work, from Baltimore to Porto Rico, on the *Blake*, then in command of Captain R. L. Faris, the present assistant superintendent, magnetic observations, comprising the magnetic declination, the dip, and the intensity of the magnetic force, were made daily at sea with the aid of newly installed instrumental appliances. This experience, as well as that later obtained in the conduct of the work, assisted L. A. Bauer in no small measure in the inauguration of the magnetic survey of all the oceans under the auspices of the Carnegie Institution of Washington.

In conclusion, the chief results were set forth respecting the secular changes of the magnetic elements in the United States. For no land area of similar size can the secular changes of the Earth's magnetism be so comprehensively and so accurately investigated as for the United States. This is in view of the circumstance that the magnetic survey of the United States has been going on with unbroken continuity for well-nigh three-quarters of a century, and not at irregular intervals, as has been the case in other countries.

Relation between changes in solar activity and the Earth's magnetic activity, 1902 to 1914. L. A. Bauer. Science, n. s., vol. 43, 724 (May 19, 1916). New York. (Abstract of paper presented before the American Philosophical Society, Philadelphia, April 14, 1916.)

No criterion of solar activity, whether it be the spottedness of the Sun or the faculæ, prominences, or calcium flocculi, has been found to synchronize precisely with any quantity used as an index of the Earth's magnetic activity. Thus, for example, the maximum magnetic activity in 1892 preceded the maximum sun-spot activity of that period by a year. So, again, the recent minimum magnetic activity of the Earth seems to have occurred in 1912, whereas the minimum sun-spot activity did not take place until 1913, or a year later.

[1] Nearly one-third of the publications have appeared during the period 1899–1915.

Then, again, the amount of magnetic activity is not necessarily commensurate with that of solar activity, whatever measure of the latter be used. When the comparisons between the solar data and magnetic data are made for intervals of less than a year, a month for example, as was done in the author's 1909 paper[1], the lack of exact synchronism and the lack of proportionality between the two sets of changes become especially noticeable.

Fortunately, beginning with 1905, we have a new set of figures, the values of the solar constant, determined with high precision at Mount Wilson, California, by Dr. Abbot. Remarkable fluctuations are shown in these values, amounting at times to 10 per cent of the value. The present paper made a comparison between the annual changes in the values of the solar constant for the period 1905 to 1914 with the irregularities in the annual changes of the Earth's magnetic constant. It is found that the two sets of data, in general, show similar fluctuations. Also, a closer correspondence is found between these two sets of changes than between either set and that of sun-spot frequencies. In brief, the solar-constant values furnish another index of changes in solar activity which may be usefully studied in connection with minor fluctuations in the Earth's magnetism.

In conclusion, it was pointed out why none of the mentioned criteria of solar activity can be used as an adequate measure of the various ionizing agencies ultimately responsible, according to present belief, for the magnetic changes recorded on the Earth.

Our Earth a great magnet. L. A. Bauer. Journ. Frank. Inst., vol. 181, 601–628 (May 1916) Philadelphia.

This was the annual lecture of the Carnegie Institution of Washington for 1915, being given before the Trustees and their guests at Washington on December 9, 1915. Although three centuries have elapsed since Gilbert in his famous treatise on the magnet, published in 1600, declared "the terrestrial globe itself is a great magnet," the only improvement which we might make would be to say: If the Earth is not a magnet, it certainly acts like one.

Since every magnet is surrounded by the so-called magnetic lines of force, then, since the Earth acts at least like a magnet, it also must be similarly enveloped. It is the object of magnetic surveys to map out these lines of force of the Earth. The Earth's magnetic poles are, on the average, 1,200 miles and more distant from the Earth's true or geographic poles, and they are not even on opposite sides of the Earth. If a straight line were drawn through the Earth's magnetic poles, it would not pass through the Earth's center, but be 750 miles away from it. Owing to the complexity of the Earth's magnetization, the compass does not point exactly north and south, except at very few places. Furthermore, the compass is continually changing its direction, by amounts which make it necessary to issue new magnetic charts for the use of mariners at intervals preferably not over 5 years. There is thus made apparent not only the need of magnetic surveys, but, likewise, the repetition, from time to time.

The extensive magnetic-survey work conducted by the Carnegie Institution of Washington, through its Department of Terrestrial Magnetism, on land and at sea, was next described, and the various operations were illustrated by showing lantern-slides and motion pictures taken on the *Carnegie's* cruise in 1915 from Brooklyn to Panama.

The belief is becoming current that every rotating member of the solar system is surrounded by a magnetic field, and astronomers are much interested at present in ascertaining whether outstanding astronomical motions which

[1]See *Terr. Mag.*, vol. 19, 116–119, 1914.

can not be explained by gravitation forces may not have to be ascribed to interacting planetary magnetic effects. It is thus seen that the problems of the Earth's magnetism, or of magnetism in general, lead to the very outer boundaries of human knowledge. They may play an important part in the solution of questions of a fundamental nature. (See pp. 321 and 330.)

Note on rotation periods of planets. L. A. Bauer. (Read before meeting of American Astronomical Society at Swarthmore, August 31, 1916.)

If magnetic fields result from the fact that the bodies which they envelop rotate about certain axes, the question of the rotation-periods of planets and the direction of rotation, becomes one of interest to the student of cosmical magnetism. Unfortunately, only in the case of half of the planets, namely, the Earth, Mars, Jupiter and Saturn, is the period of rotation and the direction of rotation definitely known.

In putting together all known facts regarding the planets, it was noticed that for the four named the product of the angular velocity of rotation, ω, into the orbital velocity of the planet about the Sun, v, hence ωv, was a constant quantity within about 14 per cent of its mean value. Thus taking ωv as unity for the Earth, we have for Mars 0.80, for Jupiter 1.05, and for Saturn 0.76; the mean value for the four planets is 0.90.

On the results of some magnetic observations during the solar eclipse of August 21, 1914. L. A. Bauer and H. W. Fisk. Terr. Mag., vol. 21, 57–86 (June 1916). Washington.

This is a compilation and discussion of observations made by and in cooperation with the Department of Terrestrial Magnetism respecting a possible magnetic effect during the time of the solar eclipse of August 21, 1914. In accordance with L. A. Bauer's circular letter of June 23, 1914, magnetic and allied observations were made at 23 stations distributed over the Earth, the results of which are tabulated in this paper.

A preliminary review of the magnetic results is next given. Confining chief attention to the stations nearest the belt of totality, the following conclusion is drawn:

"There appears to be good reason for believing that an observable magnetic effect occurred during the time of the solar eclipse of August 21, 1914, at stations within the region of visibility, the effect being larger for stations near the belt of totality than for those farther away."

A diagram showed the magnetic-declination changes at Eskdalemuir, Stonyhurst, Kew, and Rude Skov, August 21, 1914. A bay occurred at each of these stations a few minutes before the time of maximum obscuration. As the result of this bay, the customary progression of the compass needle towards a westerly extreme was interrupted, and a retrograde movement occurred which continued for some time. Of the four stations, the bay was most developed at Rude Skov (Denmark), the nearest one, of the present list of stations, to the belt of totality. The total range of this minor oscillation was at Rude Skov, about 2′, or the amplitude was 1′, which is the order of magnitude of similar oscillations observed at some previous eclipses.[1]

The Greenwich mean time of the lowest point of the bay occurred later and later in passing from Eskdalemuir to Rude Skov, and approximately, according to the same rate that the phase of maximum obscuration progressed from station to station. The occurrence of a magnetic effect at various stations, not at the same absolute time nor at the same local time, but related in some manner to the rate of progress of the shadow cone, may have to be regarded as one of the chief characteristics of a possible eclipse effect.[1] This

[1]See, L. A. Bauer's articles in *Terr. Mag.*, vol. 5, 143–165, 1900, and vol. 7, 155–192, 1902.

fact serves to differentiate an eclipse magnetic effect from a general, or terrestrial, effect such as might be associated with sun-spot activity. The difference in Greenwich mean time for the average of the three observatories in Great Britain and the Danish Observatory is 18^m, and is in the same direction as the difference in time of the phase of maximum obscuration of the eclipse. The difference in local mean time is $1^h\ 16^m$. When data from stations within the totality belt are available, the difference in time of the magnetic effect may be further investigated.

The declination bay is not found developed in the same manner at stations outside the zone of visibility of the eclipse. This fact leads to the presumption that it was not an effect due to the disturbance of the magnetic state of the entire Earth, but was more or less restricted approximately to the region in which the eclipse was visible.

The subject of a possible eclipse magnetic effect is of sufficient theoretical importance to merit further careful investigation. It is hoped that advantage may be taken of the next favorable opportunity, which will occur in the United States during the total solar eclipse of June 8, 1918.

[Since the publication of the results described above, the magnetic observations, made during the solar eclipse of August 21, 1914, at the magnetic observatory, De Bilt, Holland, have been received, and the declinations confirm the progression in the times when the marked bay occurred. The lowest part of the bay was at De Bilt at $12^h\ 09^m$ Greenwich mean time, thus falling between the times for Kew ($12^m\ 01^h$) and Rude Skov ($12^h\ 15^m$), in accordance with the respective times of maximum obscuration at the three stations.]

Researches of the Department of Terrestrial Magnetism (vol. III): Ocean magnetic observations, 1905–1916, and reports on special researches. L. A. Bauer, W. J. Peters, J. A. Fleming, J. P. Ault, and W. F. G. Swann. Quarto. Carnegie Institution of Washington Publication No. 175 (vol. III). 1916.

This volume presents the final results of all magnetic observations made at sea, on the chartered vessel, the *Galilee*, 1905 to 1908, and on the specially constructed vessel, the *Carnegie*, 1909 to 1914, as also the results of the shore magnetic observations made in connection with the work of the two vessels. Furthermore there are given the preliminary results of the magnetic observations made on the *Carnegie*, 1915–1916 (September). The "Tables of Results" contain the values of the magnetic declination, the inclination, and the horizontal intensity of the Earth's magnetic field. For the *Galilee* ocean-work there are 443 stations and for the *Carnegie* 2,807, making a total for the two vessels of 3,250 stations.

After a general introduction and a brief account of previous ocean magnetic surveys, the magnetic work of each vessel is treated separately. The headings of the main chapters or sections for the *Galilee* work are: General remarks and description of the *Galilee;* synopses of the *Galilee's* cruises, 1905–1908; methods of work on the *Galilee;* magnetic instruments and list of instruments used in the *Galilee* work; specimens of observations and of computations (during swing of vessel and on course); shore magnetic work; determination of geographic position at sea; reduction formulæ and determination of constants; ship constants and deviation coefficients; specimen computations of deviation-coefficients; ocean magnetic observations on the *Galilee* and tables of results, 1905 to 1908; shore magnetic observations for the *Galilee* work, 1905 to 1908; extracts from Director's instructions for cruises and observational work; extracts from commander's field reports and abstracts of the log of the *Galilee*; discussion of alidade corrections for standard compass; and auxiliary observations.

The section headings for the *Carnegie* works are in general the same, except that, since the *Carnegie* is a non-magnetic vessel, the sections dealing with the determination and discussion of deviation corrections are omitted. The construction of the *Carnegie* in 1909 is described and illustrated. The synopses of cruises are for the period 1909–1916 (September).

A special feature of the *Carnegie* work is the full account of the new instruments devised by various members of the Department of Terrestrial Magnetism, and constructed in the Department's instrument-shop. Thus there are descriptions and illustrations of the marine collimating-compass for magnetic declination, the sea deflector for horizontal intensity and declination, the sea dip-circle for inclination and total intensity, the marine earth-inductor for inclination, and a reversible gimbal stand. The descriptions also give the scheme or method of observation with each instrument.

The section on geographic position at sea is given special treatment under the *Carnegie* work, and specimens of observations and computations are added.

A brief account is given also of special investigations, fuller publication being reserved for a future volume. The tests made from time to time showed the absence, for the *Carnegie*, of any deviation corrections large enough to require being considered. A general statement, accompanied by diagrams, is made regarding the extent and character of the corrections which the existing magnetic charts require in order to make them conform to the observations on the *Galilee* and the *Carnegie*.

Under extracts from the commander's field reports are found, among other matters, notes on the occurrence of thunder at sea as observed on the *Carnegie's* cruise, 1915–1916, and an account of the *Carnegie's* sub-Antarctic voyage, 1915–1916. The special reports deal with the results of the atmospheric-electric work on board the *Galilee*, 1907–1908, and on the *Carnegie*, 1909–1916 (April) and contain some discussions concerning magnetic chart corrections and secular variations of the magnetic elements.

Results of atmospheric-electric observations made aboard the *Galilee* (1907–1908) and the *Carnegie* (1909–1916). L. A. Bauer and W. F. G. Swann. (One of the "Reports on Special Researches" contained in "Ocean Magnetic Observations," 1905–1916.)

The paper commences with an Introduction by L. A. Bauer, in which are summarized the considerations which govern in determining the extent of the program of scientific work possible aboard such vessels as the *Carnegie* and *Galilee*. The importance of speedy reduction and discussion of accumulated scientific data is emphasized, so that information as to the direction in which the observations are leading may follow closely upon the observations themselves. References are cited showing that the pioneer investigators in atmospheric electricity strongly urged the foundation of a world-wide atmospheric-electric survey, especially when such could be undertaken in conjunction with a magnetic survey. The Introduction concludes with a brief historical sketch of the development of the atmospheric-electric work of the Department of Terrestrial Magnetism.

Next is given a compilation of the main atmospheric-electric results obtained at sea by the Department since 1907, as based on the field reports. The details of the work up to the end of the *Carnegie's* third cruise in 1914 have already been published in various papers in the *Journal of Terrestrial Magnetism and Atmospheric Electricity*, and abstracts have appeared in previous annual reports.

A greatly increased program of atmospheric-electric work was undertaken on the *Carnegie's* fourth cruise (1915–1916), and the paper contains a full

account and discussion by W. F. G. Swann of the results obtained on this cruise. The general account of the atmospheric-electric equipment and of the methods of measurement employed is sufficiently covered in the abstract of W. F. G. Swann's paper "The atmospheric-electric work of the Department of Terrestrial Magnetism," given on pages 334–337 of the 1915 Annual Report published in Year Book No. 14. (For details of cruise, see pages 317–318 of the same report and pages 294–303 of present report.)

The observations from New York to Colon were made by S. J. Mauchly and H. F. Johnston. From Balboa (April 12, 1915) until the return of the vessel to Lyttelton, New Zealand, on April 1, 1916, after her sub-Antarctic voyage, they were made by Observers H. F. Johnston and I. A. Luke, and thereafter Observers B. Jones and I. A. Luke carried on the work. The following are the atmospheric-electric quantities measured: (1) The potential-gradient X; (2) the conductivities (λ_+ and λ_-) arising from the positive and negative ions; (3) the numbers (n_+ and n_-) of positive and negative ions per cubic centimeter; (4) the number (R) of pairs of ions produced per cubic centimeter per second in a closed vessel; (5) the radioactive content of the atmosphere; and (6) the radioactive content of the sea-water.

TABLE 4.—*Mean values of atmospheric-electric elements, uncorrected for diurnal variation.*

Leg of cruise	n_+	n_-	$\frac{n_+}{n_-}$	λ_+ (E.S.U. $\times 10^{-4}$)	λ_-	v_+ $\left(\frac{\text{cm.}}{\text{sec.}} / \frac{\text{volt}}{\text{cm.}}\right)$	v_-	X $\left(\frac{\text{volt}}{\text{m}}\right)$	i (E.S.U. $\times 10^{-7}$)	R	Ra. Em. $\left(\frac{\text{curies} \times 10^{-12}}{\text{m}^3}\right)$
Brooklyn-Colon (Mar. 9 to Mar. 24, 1915).	501 (8)	485 (8)	1 03 (8)	0 92 (8)	0.78 (8)	1 28 (8)	1 12 (8)	117 (10)	5 8 (8)	3 2 (3)	
Balboa-Honolulu (Apr. 12 to May 21, 1915).	859 (31)	801 (31)	1 12 (31)	1 57 (31)	1.36 (31)	1 31 (31)	1.25 (31)	119 (32)	11 2 (31)	3.8 (31)	4.0 (31)
Honolulu-Dutch Harbor (July 3 to July 20, 1915).	782 (15)	642 (13)	1 28 (13)	1.43 (14)	1.13 (14)	1.36 (14)	1.32 (13)	121 (15)	9 9 (14)	4.0 (13)	1.5 (10)
Dutch Harbor-Lyttelton (Aug. 4 to Nov. 2, 1915).	853 (71)	698 (67)	1.24 (67)	1.52 (68)	1.29 (66)	1.28 (67)	1.34 (65)	120 (72)	10.7 (66)	3.7 (71)	3.2 (57)
Lyttelton-S. Georgia (Dec. 6, 1915, to Jan. 12, 1916).	797 (20)	623 (21)	1 31 (20)	1.41 (23)	1.11 (23)	1.32 (20)	1 31 (20)	143 (24)	11 3 (22)	4.0 (22)	
S. Georgia-Lyttelton (Jan. 15 to Apr. 1, 1916).	838 (44)	706 (42)	1 20 (42)	1 47 (39)	1 21 (39)	1.28 (37)	1 24 (36)	120 (47)	10.7 (39)	3 9 (45)	0.4 (48)

The meteorological observations which are made are: pressure, temperature, humidity, extent and nature of clouds, wind strength and direction.

The diurnal variations of the potential-gradient, ionic content for the positive ions, and penetrating radiation are also under investigation. The specific ionic velocities v_+ and v_- for positive and negative ions are given by the relations $v_+ = \lambda_+/n_+e$, and $v_- = \lambda_-/n_-e$, respectively, e being the electronic charge, and the air-earth current-density i is obtained from the relation $i = (\lambda_+ + \lambda_-) X$.

The mean values of the atmospheric-electric quantities for each leg of the cruise are recorded in table 4, the numbers of days on which observations were taken being recorded in parenthesis under each value given. The last column gives the radium-emanation content in curies $\times 10^{-12}$ per cubic meter. The results for the potential-gradient, ionic content, and conductivity in table 4 all correspond approximately to the time $9^h.6$. Of the values from Brooklyn to Colon, more than half were obtained in the landlocked

Caribbean Sea, and the remainder just to the north of the West Indies. They thus correspond to a region of the sea near to land, and while they are in harmony with the results of former ocean observations in indicating exceptionally small values for the conductivity and ionic content in such regions, they are not to be taken as typically representative of ocean values.

Table 5 shows the observations grouped according to the scheme indicated in the first column of the table. The values of n_+, n_-, λ_+, λ_-, X, and i are here reduced to daily mean values with the aid of the diurnal-variation results obtained throughout the cruise, and on the basis of the rough assumption that the diurnal variations of n_-, λ_+, and λ_-, are the same as that of n_+. It was further assumed that the mean diurnal-variation curves for the whole cruise are sufficiently appropriate ones to use for the purposes of the reductions. R showed no diurnal variation, and so needed no reduction. Except in the case of the radioactive content, there is a very close agreement

TABLE 5.—*Mean values of atmospheric-electric elements, corrected for diurnal variation.*

Ocean	n_+	n_-	$\frac{n_+}{n_-}$	λ_+ (E S U $\times 10^{-4}$)	λ_-	v_+ $\left(\frac{cm}{sec}/\frac{volt}{cm}\right)$	v_-	X $\left(\frac{volt}{m}\right)$	i (E S U $\times 10^{-7}$)	R.	Ra Em. curies $\times 10^{-12}$ / m^3
Pacific	811	692	1 21	1 46	1 24	1 30	1 31	109	9 4	3 8	3 3
Sub-Antarctic	792	651	1 23	1 39	1 12	1 29	1 26	119	9 9	3 9	0 4
Means for Pacific and sub-Antarctic	802	672	1 22	1 42	1 18	1 30	1 28	114	9 6	3 8	1 8
Direct means of all observations in Pacific and sub-Antarctic	804	677	1 22	1 44	1 19	1 30	1 30	113	9 5	3 8	2 2

between the corresponding values for the Pacific and sub-Antarctic Oceans. The mean value 113 volts per meter, for the potential-gradient, is in general agreement with former ocean determination and is of the same order of magnitude as the mean of several land values, 151 volts per meter.

TABLE 6.—*Comparison of former land and sea values with those of the fourth cruise.*

Nature of observations	n_+	n_-	$\frac{n_+}{n_-}$	λ_+ (E S U $\times 10^{-4}$)	λ_-	v_+ $\left(\frac{cm}{sec}/\frac{volt}{cm}\right)$	v_-	i (E S U $\times 10^{-7}$)
Mean of land observations obtained by various observers	737	668	1 23	1 30	1 23	1 08	1 22	6 5
Mean of ocean values for the *Carnegie's* fourth cruise	804	677	1 22	1 44	1 19	1 30	1 30	9 5
Mean of former ocean values obtained by various observers	736	588	1 28	1 44	1 20			

Table 6 shows a comparison of the results for the *Carnegie's* fourth cruise with the means of a large number of former ocean and land determinations. The agreement between the fourth cruise values and the others quoted is, in general, remarkably close, and, in particular, the former values confirm the important conclusion that the ionization over the ocean is practically the same as that over the land. The ocean values of v_+ and v_- are somewhat

greater than the land values and are, moreover, more nearly equal to each other, and to the values obtained in laboratory experiments made with dust-free air. This result is what might be expected in view of the purity of the ocean air. The values of R (see table 5) show a remarkable constancy, and are in good agreement with the results of Simpson and Wright, who found values of this quantity in the south Atlantic and south Indian Oceans ranging from 4 to 6.

The mean value of the radium-emanation content for the whole cruise forms only about 2 per cent of the average value found over the land, and is far too small to contribute in any marked degree to the ionization over the ocean. It is, nevertheless, of interest to remark that the difference between the radium-emanation contents for the Pacific and sub-Antarctic Oceans is in the right direction, and of the right order of magnitude, to account for the slight difference in the ionic contents observed over these oceans. The emanation content, though small, shows, throughout the cruise, a very decided variation with the distance from land and with the wind direction, the variation being of the type to be expected on the view that the land is the primary source of the emanation.

In order to explain the ionic content over the ocean it is necessary to account for a rate of production of about 1.6 ions per cubic centimeter per second. The source responsible for the ionization in a closed vessel is amply sufficient to provide for the necessary rate of production of ions, if we are justified in attributing an appreciable fraction of this ionization to causes other than the vessel itself. The radioactive material in the soil and in the air over the land are, however, sufficient to account for a rate of production of 4.5 ions per cubic centimeter per second, so that the main difficulty resulting from a comparison of the ionic densities over land and sea is to be found not so much in accounting for the latter as in accounting for the fact that the ionization over land is not much greater than that over the sea. It would seem that the explanation of the difficulty must be sought in the slowly moving ions (large ions) formed by the union of the so-called small ions with dust nuclei. The large ions are not measured by the ion-counter, but they have to be maintained, since they are continually suffering recombinations. It turns out that, if we assume the number of large ions over the ocean to be insignificant, it is necessary to assume for the land a number of large ions per cubic centimeter about equal to the number of small ions per cubic centimeter in order to account for the fact that the measured ionic density over the land is no greater than that over the sea.

The potential-gradient shows a distinct diurnal variation, and the mean diurnal variation curve for the whole cruise gives minima about 5 a. m. and 3 p. m., and maxima about 9 a. m. and midnight. These results are in general agreement with those of Simpson and Wright, who, in 1910, made a few determinations of the diurnal variation of the potential-gradient in a region of the ocean within 40° of the Equator. The Fourier analysis of the diurnal-variation curve for the *Carnegie's* fourth cruise shows the amplitude of the 12-hour "wave" to be greater than that of the 24-hour "wave," a result of considerable importance in connection with the theory of the origin of the former.

The rate of production of ions in a closed vessel shows no appreciable diurnal variation; the ionic content, however, shows a distinct variation, with a flat maximum extending from about 6 a. m. to 2 p. m., and a minimum at midnight. The diurnal variation of the ionic content is of the type to be anticipated from the secondary influences resulting from the diurnal variations of potential-gradient, and temperature.

Concerning the origin of the Earth's magnetic field. L. A. Bauer. (Presented before the Philosophical Society of Washington, October 14, 1916.)

The various recent theories regarding the origin of the Earth's magnetic field were reviewed with particular reference to their bearing on the general topic: the constitution of the Earth's interior. The hypothesis of chief interest in this connection, namely, that of an iron core being the cause of terrestrial magnetism, has inherent in it many difficulties, which, however, may not be insuperable. Should experiments decisively show that increased pressure elevates the critical temperature of magnetization, then the depth of 10 to 12 miles, now supposed to limit the presence of materials in the magnetic state, would be increased. However, the few experiments available indicate that increased pressure lowers the critical temperature of magnetization.

The various hypotheses as to the Earth's magnetic field being caused by electric currents within the Earth's crust, or that the field is connected in some manner with the speed and direction of rotation of the Earth, were briefly discussed. The exceedingly small effect to be observed renders conclusive laboratory experiments, if not a hopeless task, certainly a very difficult one with present appliances.

The author reiterated a belief, already expressed on a former occasion, that our chief hope at present of determining the origin of the Earth's magnetic field, appears to be in the direction of determining what causes the field to vary in the remarkable manner it does. The definite limitations imposed by the variations in the Earth's magnetic field, both of the periodic and aperiodic kind, and the departures of the field from the simple uniform type, are too frequently overlooked by theorists. Most theories, for example, are found inadequate when the attempt is made to explain, besides the origin of the field, the secular variation as it is actually observed.

In conclusion it was pointed out that the solution of some of the questions entering into the problem of the origin of the Earth's magnetic field must be deferred until the completion of the magnetic survey of the Earth now in progress under the auspices of the Carnegie Institution of Washington.

On the improvement of the direct-recording declinograph. W. G. Cady.

The report covers the experimental work[1] done since 1909, and describes the additional improvements in design and theory of the direct-recording declinograph.[2] The record made by the instrument was found to be affected by temperature effects caused chiefly by expansion and contraction of the horizontal brass arm from which the magnet was suspended; this effect has been eliminated by using, instead of the single supporting-post, two posts. The ink-reservoir formerly carried by the pen has been made fixed and the butt end of the pen bent down to extend into the fixed reservoir; the weight of the pen is thus made constant and the balance of the movable pen is improved. The difficulty arising from jarring of the rocker-arm carrying the record-paper has been eliminated by introducing a dash-pot with a specially devised by-pass. A winding device has been added to automatically reel up the record-paper as it comes from the instrument.

The record-paper heretofore used has been replaced by a paper received from the Leeds and Northrup Company of Philadelphia; the new paper practically does away with the blurring of the slow-drying ink previously

[1]The work was done by Professor Cady at Wesleyan University, Middletown, Connecticut, with the cooperation of the Department of Terrestrial Magnetism.

[2]For description of the instrument and of its theory see *Terr. Mag.*, vol. 9, pp. 69–80, 1904, and vol. 11, pp. 145–152, 1906.

experienced. Numerous experiments were made during the search for more suitable ink or paper to improve the clearness and sharpness of the record; thus it was attempted to adapt the principle of the thread-recorder as made by the Cambridge Scientific Instrument Company, and also to replace the ink by singeing the paper at each contact by means of an electric current and a small V-shaped loop of fine platinum wire attached to the end of the "pen." The latter method promised excellent results, but the experiments were discontinued when the supply of new paper was secured and found so satisfactory.

The treatment of the theory of the instrument was extended, and as a result of the new discussion it was found possible to make the scale-value more uniform throughout the width of the record. In the original form of the instrument, the magnet-lever was vertical and the pen-lever was horizontal; thus while the length of the magnet-arm was constant, the length of the pen-arm became longer as the deflection from the axial line of the instrument increased, and the scale-value was greater at the edges of the paper than in the center. This difference, which amounted to several per cent, was materially reduced by inclining each of the two levers at an angle of 45° with the horizon. In that case, as the changing declination turns the pen-arm from its mean position, the effective lengths of both levers increase and hence the ratio of the angular displacement of the magnet to the angular displacement of the pen, *i. e.*, the scale-value, is more nearly uniform. It is even possible by carefully choosing the two angles of inclination and by curving one or both of the levers to make the scale-value perfectly uniform across the paper; that degree of refinement is, however, unnecessary and would be inadvisable owing to the probable increase in friction.

Some notes on the occurrence of thunder at sea. W. J. Peters. Terr. Mag., vol. 21, pp. 21–22 (Mar. 1916). Washington.

Baron von Humboldt appears to be responsible for the statement that thunder is never heard on the ocean at any great distance from land, though violent thunderstorms are often observed at sea and vessels are frequently struck by lightning. Since this statement has provoked discussion from time to time, observations are being made aboard the *Carnegie*, under J. P. Ault's command, in accordance with directions issued to the vessel by the Director of the Department of Terrestrial Magnetism. The present paper summarizes the results of the observations made on the voyage from Dutch Harbor, Alaska, to Port Lyttelton, New Zealand, between August 6 and November 2, 1915. Final conclusions are deferred pending receipt of additional data.

The normal electric field of the Earth. W. F. G. Swann. (Presented before the Philosophical Society of Washington, October 2, 1915.)

The paper comprised: (1) A general review of the principal atmospheric-electric phenomena; (2) a discussion of the extent to which the known causes contributing to atmospheric ionization are sufficient to account completely for such ionization; (3) a discussion of the origin and maintenance of the Earth's charge.

The chief sources of atmospheric ionization in the lower atmosphere are the radioactive materials in the soil and atmosphere, and the penetrating radiation. Over the sea, the radioactive material is insufficient to account for an appreciable fraction of the ionization observed there. If, however, we are correct in assuming that an appreciable fraction of the ionization produced in a closed vessel is produced as a result of actions other than that of the vessel itself, the cause responsible for such ionization is amply sufficient

to account for the ionic content over the ocean. The radioactive material in the air over the land and in the soil is sufficient by itself to account for more than the ionization as ordinarily observed there with the Ebert ion-counter, so that there is a surplus to account for the existence, over the land, of a large number of the so-called "Langevin ions," which on account of their small mobility are not measured with the Ebert apparatus.

The part of the paper dealing with the origin and maintenance of the Earth's charge was, in its essentials, the same as the author's paper published in Terrestrial Magnetism, volume 20, pages 105–126, 1915, and abstracted on pages 339–341 of the 1915 annual report, published in Year Book No. 14.

Atmospheric-electric observations made aboard the *Carnegie*. W. F. G. Swann. (Presented before Section II, Second Pan-American Congress at Washington, January 3, 1916.)

The paper commenced with a brief review of the atmospheric-electric problems awaiting solution, and a statement of the reasons which cause a peculiar interest to attach to ocean observations. A description was then given of the atmospheric-electric equipment aboard the *Carnegie* on her fourth cruise. The paper concluded with a discussion of the 1915 results of the *Carnegie's* fourth cruise. (See pages 326–329).

On the ionization of the upper atmosphere. W. F. G. Swann. Terr. Mag., vol. 21, pp. 1–8, 1916.

From various points of view there are indications that the upper atmosphere is to be treated as a region of relatively high electrical conductivity. In so far as ultra-violet light is frequently considered as one of the main ionizing agencies in the upper atmosphere, it is of interest to calculate the amount of ionization to be expected from this source when the Sun is treated as a black body.

Applying the Planck radiation formula, and assuming, in accordance with the experiments of Hughes, that, for air, ionization does not set in below wave-length 135 $\mu\mu$, it appears that only about 1.6×10^{-5} of the total solar radiant energy is available for atmospheric ionization.

In an example quoted by Schuster in connection with his theory of the diurnal variations of terrestrial magnetism it is shown that, if the upper atmosphere is treated as a shell 300 km. thick, at a pressure of 1 dyne per square centimeter, a conductivity of 10^{-13} E.M.U. would have to exist in the shell in order to account for the magnetic effects under discussion. If the conductivity be taken as $2ev(q/\alpha)^{\frac{1}{2}}$, where q is the rate of production of pairs of ions per cubic centimeter, α the coefficient of recombination of the ions, e the electronic charge, and v the specific ionic velocity, it becomes possible to calculate λ if q, v, and α, are known. Assuming the value $h\nu$ for the energy necessary to produce an ion, h being Planck's constant and ν the frequency corresponding to the wave-length 135 $\mu\mu$, q can be calculated for a case where the ionization is uniform throughout the 300 km. layer, and is all due to the ultra-violet light. Assuming further that the laws governing the variations of α and v down to the pressure and temperature of the 300 km. layer are the same as those deduced from laboratory experiments, the conductivity to be expected in this layer as calculated in this manner, is only about 10^{-3} of the value 10^{-13} E.M.U. required for the magnetic problem. Even if the whole of the Sun's energy could be utilized in producing ionization, the conductivity accounted for would still be far too small. Any departure from a condition of uniform ionization in the layer would act in the direction of reducing still further the conductivity to be accounted for by the ultra-violet light.

The above conclusion is not intended as a criticism of Schuster's theory, however, since, as Schuster himself points out, the ultra-violet light is not the only source of ionization in the upper atmosphere. Further, in the paper here abstracted, it is shown that, if the calculation is not limited to a shell, and account is taken of the infinite extent of the atmosphere, the magnetic effects which result as the ultimate consequence of a feeble source of ionization may be very much greater than those calculated on the basis of a shell of finite thickness.

Reply to E. H. Nichols's article (investigation with regard to the induced charge on the Ebert electrometer at Kew Observatory). W. F. G. Swann. Terr. Mag., vol. 21, pp. 99–102, 1916.

In a previous paper (Terrestrial Magnetism, vol. 19, pp. 205–218, 1914), the author developed a theory of the action of the potential-gradient in modifying the results obtained in certain atmospheric-electric instruments. One of the instruments under discussion was the Ebert electrometer. To illustrate his theory the author applied it to the experimental data obtained from one type of Ebert instrument, and found that in the case of this instrument a potential-gradient of 70 volts per meter would result in an error of 26 per cent on the measured ionic density of the negative ions, if the specific velocity of the ion were assumed to be 1.5 cm. per second per volt per centimeter.

In the June number of Terrestrial Magnetism and Atmospheric Electricity for 1916 (pages 87–98), E. H. Nichols quotes the results of his analysis of the Kew data for several years, and also the results of special experiments made by him for the purpose of investigating the error in the Ebert instrument. He comes to the conclusion that when the instrument used at Kew is provided with the cap supplied by the makers, the error in question is much smaller than 26 per cent. He concludes that Swann's theory of the matter is of limited application, that it omits to consider the effect of the wind and of the cap, and that it applies only to a cylindrical opening. When the cap is absent, however, he finds that errors as high as 40 per cent may result, and admits that under these conditions his results appear to support Swann's conclusions.

In Swann's reply to the above criticisms he points out that his theory of the matter does not neglect the effect of the wind, nor is it restricted to a circular opening, or to a case where the instrument is unprovided with a cap, and he cites references to his original paper showing that these matters have been included in his theory. He points out, however, that his formula gives the error in terms of a quantity which must be *experimentally determined for the apparatus used.* His own experiments were made primarily for illustration; the instrument used was not provided with a cap, for a large amount of published material has been obtained with such instruments, and even in some modern forms of Ebert electrometer there is no cap. His theory, however, in no way denies the possibility of the existence of a much smaller error in the type of apparatus used at Kew. In fact, his formula provides no information whatever as to the *magnitude* of the error until the experimental data appropriate to the instrument have been substituted in it. Further, he calls attention to the fact that his theory shows the error to be proportional to the specific ionic velocity, and that, as pointed out in his paper, he used the value 1.5 cm. per second per volt per centimeter for this quantity. If he had used the very low value 0.5 cm. per second per volt per centimeter, which E. H. Nichols quotes as appropriate for Kew, he would have calculated an error of only 8.7 per cent instead of 26 per cent. Quite apart from all other con-

siderations, therefore, the apparent discrepancy between his conclusions and those of E. H. Nichols is greatly reduced by this circumstance.

In conclusion, reference is made to certain experiments by E. H. Nichols to test the electric field in the immediate vicinity of the cap of the electrometer. It is pointed out that the results so obtained, if driven to their logical conclusion, would indicate that even in the capped form of instrument there is a considerable error, a result inconsistent with the conclusions which E. H. Nichols draws from his other experiments and recorded data.

On the magnetic and electric fields which spontaneously arise in the vicinity of rotating conducting spheres. W. F. G. Swann.

There are several ways in which small magnetic and electric fields may be conceived as arising in the vicinity of a rotating body. Thus, centrifugal force will make the free electrons move away from the axis of rotation, until the electrostatic forces brought about as a result of this phenomenon restore equilibrium. The rotation of a body, a sphere for example, may accordingly be expected to result in the generation of magnetic and electric fields from this cause alone. Again, in so far as the electrons are pulled by gravity, they will tend to move towards the center of the sphere and will do so until the electrostatic forces, etc., resulting from this action restore equilibrium. This effect also provides a reason for the existence of a magnetic field. Analogous remarks result from a consideration of the potential-gradient which arises in a sphere, from causes of the nature of the Thomson effect when the sphere is hot at the center and cold at the surface.

A very little consideration of the order of magnitude of effects such as those cited above will show, without exact mathematical analysis, that they can play no appreciable part in the explanation of the Earth's magnetism, and in the paper the results of the above effects are calculated simply as a matter of physical interest.

The three effects, centrifugal force, gravity, and temperature gradient, in the sphere (Thomson effect) are considered separately, for it is easy to see that when all act together the solution is practically that obtained by adding the individual solutions.

The distribution of electricity throughout the sphere and on its surface becomes determined by the following conditions: (1) the resulting electrical forces within the sphere must balance the mechanical force arising from the phenomena under consideration; (2) Poisson's equation must be satisfied throughout the sphere; (3) the total volume charge plus the surface charge must be zero. When the charge distribution has been obtained, the electric and magnetic potentials may readily be calculated.

Tables 7 and 8 summarize some of the main conclusions for a sphere of unit-specific inductive capacity. Table 7 gives the values of the horizontal and vertical intensities H_e and Z_p at the equator and pole, respectively, two cases being cited, that of a sphere of the density of copper and of radius 20 cm., rotating 100 times per second, and that of a sphere of the size and mean density of the Earth, rotating with the Earth's angular velocity. H is measured in the direction of increasing colatitude, and Z is measured upwards from the surface of the sphere, the direction of rotation being supposed to take place from west to east.

In the calculation of the contribution arising from the Thomson effect certain assumptions have to be made as to the theory of this effect. For the details of these the complete paper must be consulted. The fields calculated are for the case where the temperature gradient is confined to a thin shell near the surface of the sphere, and the total fall in temperature amounts to 5000° C.

TABLE 7.—*Illustration of the magnetic effects obtainable by the rotation of conducting spheres.*

Case.	Centrifugal force alone considered.	Gravity alone considered.	Thermal effects (Thomson effect) alone considered.
Nature of charge distribution.	Positive volume charge of uniform density, and equal negative surface charge of non-uniform density.	Positive volume charge and equal negative surface charge, both of uniform density.	Positive volume charge with density a function of distance from center, the form of the function depending on the conditions. The negative surface charge is uniformly distributed and its total amount is equal to that of the volume charge.
H_θ small sphere	-2.6×10^{-18} E. M. U.	5.2×10^{-30} E. M. U.	$-4\ 9\times10^{-11}$ E. M. U.
Z_φ small sphere	$+1\ 1\times10^{-18}$ E. M. U.	1.0×10^{-29} E. M. U.	$-9\ 8\times10^{-11}$ E. M. U.
H_θ for Earth..	-4.1×10^{-24} E. M. U.	$3\ 8\times10^{-22}$ E. M. U.	-5.7×10^{-18} E. M. U.
Z_φ for Earth..	$+1.7\times10^{-24}$ E. M. U.	7.3×10^{-22} E. M. U.	-1.1×10^{-17} E. M. U.

Table 8 shows the nature of the variations of the fields over the surface of the sphere for the case of an observer moving with the surface of the sphere and for the case of a stationary observer. The fields are expressed according as their direction is like or unlike that of the Earth's field.

TABLE 8.—*Comparison of types of field obtained with that of the Earth.*

Influence.	Observer fixed in space.		Observer moving with surface of sphere.	
	H	*Z*	*H*	*Z*
Centrifugal force	Like Earth, lat. 0° to 38°.5 (N and S). Unlike Earth for latitudes greater than 38°.5 (N. and S).	Like Earth, lat. 0° to 69°.8 (N. and S). Unlike Earth for latitudes greater than 69°.8 (N. and S).	Unlike Earth, lat. 0° to 26°.6 (N and S). Like Earth for latitudes greater than 26°.6 (N and S).	Like Earth, lat. 0° to 50°.8 (N. and S). Unlike Earth for latitudes greater than 50°.8 (N. and S).
Gravitational force.	Unlike Earth . .	Unlike Earth....	Unlike Earth ..	Unlike Earth.
Thomson effect...	Like Earth....	Like Earth . .	Like Earth.....	Like Earth.

The only influence which gives rise to an external electrostatic field is the centrifugal-force effect. The field is, of course, very small; it is a maximum at the poles, where it acts vertically upwards and amounts to 4.5×10^{-9} volt/cm. for the small sphere, and 2×10^{-15} volt/cm. for the large sphere. Except at the equator and poles the horizontal component of the field attains a finite value. The internal electrostatic fields are, of course, such as to just balance the mechanical forces. For the centrifugal-force effect, the field is perpendicular to the axis of rotation. On the surface, at the equator, it amounts to 4.5×10^{-9} volt/cm. for the small sphere, and 2×10^{-15} volt/cm. for the large sphere. For the gravitational and Thomson effects, the internal field is radial. For the gravitational effect, it amounts, on the surface, to 2.8×10^{-20} volt/cm. for the small sphere and 5.5×10^{-13} volt/cm. for the large sphere. For the Thomson effect it is, at each point, proportional to the temperature gradient, and amounts to 2×10^{-4} volt/cm. per gradient of 1° C.

In the latter portion of the paper the solutions of the problems are extended to fit the case of a sphere having a specific inductive capacity other than unity.

On the conduction of electricity through an ionized gas, more particularly in its relation to Bronson resistances. W. F. G. Swann and S. J. Mauchly. (Read at the meeting of the American Physical Society, Washington, April 21, 1916.)

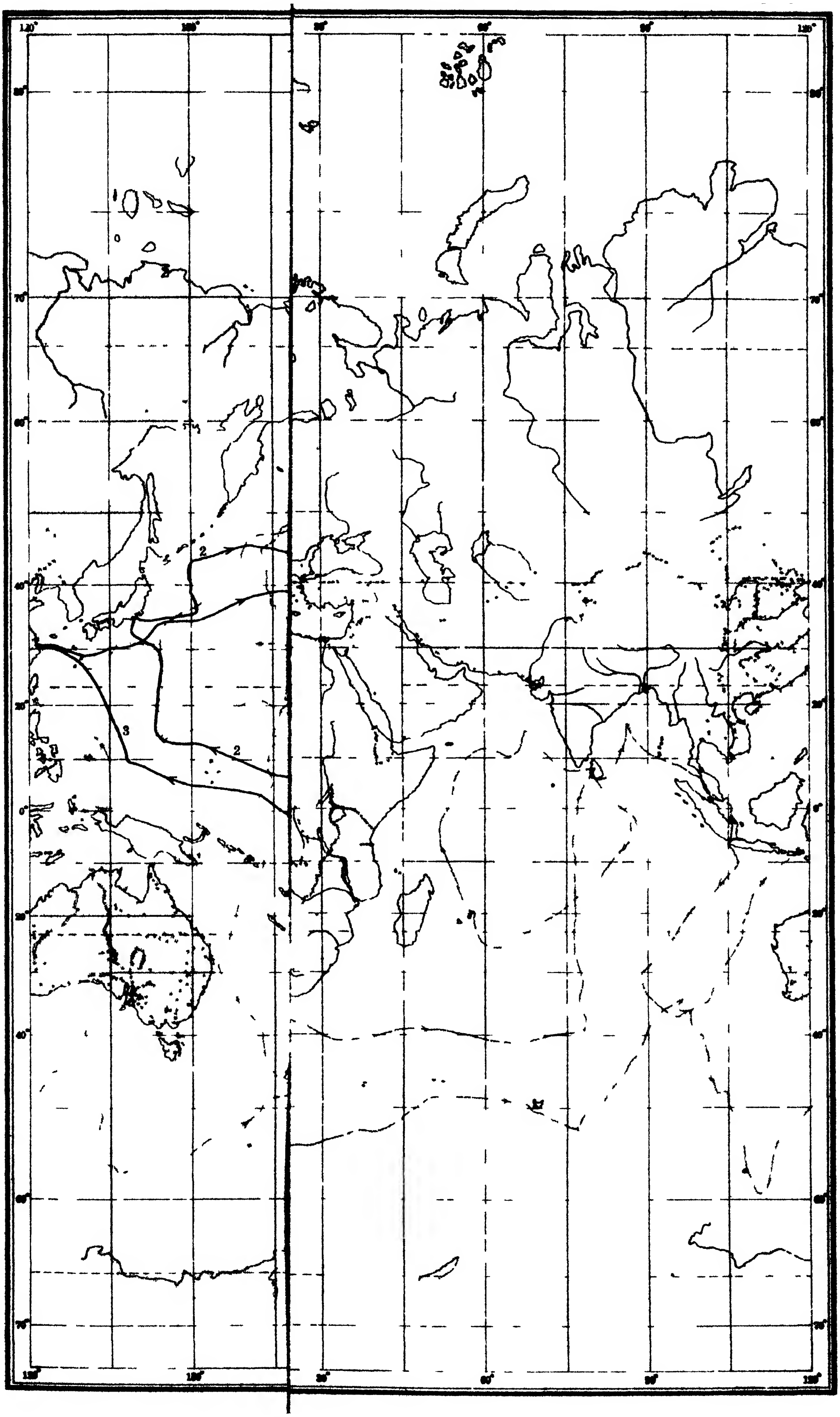
The paper forms an experimental and theoretical investigation of certain phases of the peculiarities exhibited by Bronson resistances.

In most of the experiments the active substance used was ionium. The current potential curve, in some types of cell, shows an increase of resistance with field for small fields, but as the field is further increased, the resistance starts to diminish. This phenomenon has nothing to do with ionization by collisions, since the fields concerned are too small; it is shown, however, that the behavior of the cells in the above, and in other respects, can be satisfactorily accounted for by taking into consideration the δ rays which are emitted by the α particles. The theory of the action of the δ rays in causing the current to increase more rapidly with the potential difference between the plates than would be accounted for by a linear law is practically the same as that applicable when a field is maintained between two plates, one of which is raised to incandescence so as to cause it to emit negative ions. The nature of the phenomena is such as to indicate that δ rays are emitted from the inactive plate even when the latter is out of the range of the α particles, and it is necessary to assume that these δ rays are emitted as the result of bombardment by other δ rays emitted from the active plate with speeds sufficiently high to enable them to travel across the air-space between the plates. The amount of such high speed δ-ray radiation seems very considerable, and from different standpoints it is shown that the ratio of the number of δ rays which finally appear, direct or indirectly, to the number of α particles emitted from the active plate, is much larger than the numbers which have been found in experiments at low pressures. Two *lower limits* obtained from independent standpoints indicate for this ratio values 2,500, and 4,000, respectively.

It was found that the behavior of a Bronson cell, as regards its constancy, depends largely on the nature of the material employed for the plates. In the case of aluminum, a large change in resistance was produced when the inactive plate was sandpapered; indeed, it was found impossible to secure satisfactory constancy with aluminum, the resistance fluctuating from day to day, and depending, among other things, on the time which had elapsed since the inactive electrode had last been cleaned. Effects of this kind were traced to variations in the δ-ray emission from the upper electrode as a result of time variations in the condition of its surface, these variations being somewhat analogous to those experienced in the case of the photo-electric effect. It was found that the action of the cell was greatly improved when silver plates were employed.

Since the effect of the δ-ray emission is to cause the current to increase more rapidly with the potential than would be accounted for by a linear law, while the normal departure from linearity is in the opposite direction, it is possible to choose the conditions so as to make the two effects partially compensate. In this way linearity may be obtained over fairly large ranges of potential. In practice it has been found desirable to make the inactive electrode in two parts. It consists of a large disk supported by a tube, and a smaller disk supported by a rod which slides in the tube. Approximation to the desired linear relation is then secured by suitably adjusting the positions of the parts of the compound electrode with respect to the active plate. The active material is spread over a shallow tray sunk in a thick metal plate; it is covered with a piece of thin mica hermetically sealed to the plate, and the mica is covered with silver foil held down by a silver-plated ring.

Reasons are given for the very large temperature coefficients shown by some types of Bronson cells and various other features of the cells are discussed.



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2
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ARCHEOLOGY.

Morley, Sylvanus G., Santa Fe, New Mexico. *Research Associate in American Archeology.* (For previous reports see Year Books Nos. 13 and 14.)

During the summer and fall of 1915 work on the inscriptions of Copan, Honduras, was continued. After returning from the field in June, Mr. Morley proceeded to Cambridge to examine the original texts, casts, and photographs in the Peabody Museum, Harvard University, and to incorporate this material with the results of his previous studies in a forthcoming monograph on the inscriptions at this site. (Publication No. 219.)

The 1916 Central American expedition took the field early in the year, sailing from New Orleans for Puerto Barrios, Guatemala, on February 3 and returning to this country on June 5. During this period the personnel of the party changed several times. After the highlands trip, Mr. A. W. Carpenter became the photographer and continued in this capacity until the close of the season.

Dr. George Underhill was the expedition physician for the Copan and Tuluum trips, and Dr. Moise Lafleur for the Uaxactun trip. The tragic death of the latter and of a guide, on May 17, in northern Peten, has already been made the subject of a special report to the President of the Institution.

In addition to the foregoing regular members of the staff, the expedition was peculiarly fortunate in having the services at one time or another of several other collaborators who materially increased the range of its activities. Mr. W. H. Holmes, Head Curator of Anthropology at the U. S. National Museum, accompanied the party to the ruins of Copan and made an archeological panorama of the site, which he has kindly placed at the disposal of the Institution. Mr. S. K. Lothrop, of Harvard University, was with the expedition until the end of March. He made a number of maps and plans, including a survey and archeological panorama of the ruins of Tuluum. Dr. T. Gann, chief medical officer of British Honduras, made the Tuluum trip for the purpose of copying the extensive mural paintings there, an excellent representative series of which was secured.

The itinerary of the expedition may be divided into four parts or trips, each corresponding to a well-defined unit of work: (1) the highlands of Guatemala; (2) the ruins of Copan, Honduras; (3) the ruins of Tuluum, on the east coast of Yucatan, Mexico; (4) the ruins of Uaxactun, northern Peten, Guatemala.

The objectives of the first trip were the ruins of Chinkultic and Ocosingo in the State of Chiapas, Mexico, where hieroglyphic inscriptions have been reported by Seler and others. Owing to revolutionary disturbances in this region, however, it was impossible to proceed

beyond Huehuetenango in the highlands of Guatemala, and the party returned to the capital without having reached either of its destinations.

The Copan trip was more successful. Several new inscriptions, chiefly fragmentary texts from the Archaic Period, were discovered and copied. The most notable find, however, was that of a heretofore unreported stela, which was located in the walls of the cabildo at Santa Rita, a small village 7 miles up the valley from the main group of ruins. Its several pieces were removed from this exposed position, and after the inscription had been copied and photographed, they were carried to a place of safety. The new monument—to which the number 23 has been given—dates from the early part of the Middle Period 9.11.0.0.0, approximately 380 A. D.

The third trip, to Tuluum on the east coast of Yucatan, was exceedingly fruitful. This site has long held a peculiar interest for students in the Maya field, not only because of its size and individuality, but also on account of its comparative inaccessibility and isolation.

It was first described by the American traveler Stephens, in 1840,[1] though owing to the War of the Castes, which ravaged Yucatan in 1848, it has since been closed to investigation. Maya Indians, fleeing from the victorious Mexicans in the western part of the peninsula about the middle of the last century, settled in the region around Tuluum, where they have maintained themselves in virtual independence ever since. They have successfully resisted such Mexican troops as have been sent against them, falling back into the bush before large parties and killing such small parties as have ventured into their country.

Only twice since Stephens's time has the site been visited—once by an expedition from Harvard University in 1911, and once by an expedition from the School of American Archeology in 1913. Neither party stayed at the ruins for more than 24 hours, and beyond a brief reconnaissance, little was accomplished by either.

Several circumstances made the present season especially opportune for visiting this site. Friendly relations have been established between the Mexican Government and the Maya for the first time in many years. The expedition was at Belize, the best point from which to make the trip; and finally the party was sufficiently numerous—5 investigators and assistants—to insure an adequate study of the site in a minimum of time. A small steamboat, of about 40 tons, was hired in Belize and the expedition sailed for Tuluum on March 19.

The most important result was the location of the hieroglyphic monument first reported by Stephens, and later by Howe of the Peabody Museum expedition. Howe's reading of the date as 9.6.10.0.0, approximately 290 A. D.,[2] was verified and drawings and photographs were made. The occurrence of such an early date as 290 A. D. at

[1] "Incidents of Travel in Yucatan," J. L. Stephens, vol. II, pp. 385–409.

[2] "The Ruins of Tuluum," George P. Howe. American Anthropologist, N. S, 1911, vol. XIII. pp. 539–550.

such a late Maya site as Tuluum is difficult to explain. Geographically, architecturally, stylistically, and historically considered, Tuluum is a thousand years later than the Initial Series date of this stela. Indeed, barring this one date, there is nothing at Tuluum to connect it with the Old Empire; on the contrary, its location, architecture, and mural decorations strongly indicate that it is to be referred to the close of the New Empire, probably some time after 1200 A. D. The question is an important one, and further investigation will be necessary before this apparent anachronism can be satisfactorily explained and the discrepancy between the chronological and other criteria cleared away.

Dr. Gann secured tracings of a number of the mural paintings and made the necessary color notes for their accurate reproduction. In the time available, however, it was impossible to make more than a beginning upon this important work. The subjects portrayed are exclusively of a religious nature—representations of the principal deities of the Maya pantheon in various acts of sacrifice. God B of the Schellhas classification, probably the chief Maya divinity, occurs repeatedly. The delineation of the figures so closely resembles that in the Codex Tro-Cortesiano as to strongly suggest that this manuscript originated not far from Tuluum.

A map of the religious and civic center of the city, *i. e.*, the area within the walls,[2] was prepared by Mr. Lothrop, as well as elevations and ground-plans of all the more important structures. The archeological panorama already mentioned was based upon these data and conveys an excellent idea of the city as it once appeared.

The foregoing material, together with the photographic record secured by Mr. Carpenter, now makes possible for the first time the preparation of an adequate preliminary report of this little-known site and paves the way for its more intensive investigation.

The last trip—to northern Peten—was the most profitable of the season, resulting in the discovery of a large new city and the oldest monument yet reported from the Maya field. This site, to which the name Uaxactun was given,[2] is of major importance. Although less extensive than the largest Maya cities, Tikal, Copan, Chichen Itza, and Uxmal, it may be classed with such noteworthy sites as Quirigua, Naranjo, and Nakum, and was easily a center of large population.

Time and facilities were lacking for the thorough exploration of the region, so proximate was the rainy season and so dense the tropical forests, but three large architectural complexes were located in an area not over half a mile square. Each contained numerous courts, surrounded by the remains of extensive buildings, both of the dwelling

[1]The city is inclosed on three sides by a high wall, the bluff along the sea protecting the fourth side. This wall incloses an area of some 22 acres. It varies from 8 to 13 feet in thickness at the base, and from 10 to 15 feet in height. The north and south sides are pierced by two gateways and the west side by one.

[2]Uaxactun is the Maya word for "8 stone." Uaxac = 8, tun = stone or year. The discovery of a Cycle 8 Initial Series stela here suggested the name given to the city.

and religious types, *i. e.*, palaces or monasteries and temples, and many monuments.

Group A, the first discovered, has 5 sculptured stelæ and 10 plain ones; Group B has 4 sculptured stelæ and 14 plain ones; and Group C has 2 sculptured stelæ and 4 plain ones, a total of 39, and without doubt further investigation would bring others to light. The main plaza seems to have been at Group B, and here the most important monuments as well as the largest pyramid-temple were found. The most important monument is easily Stela 9 at Group B, which was found to record a Cycle 8 Initial Series as follows: 8.14.10.13.15, approximately 50 A. D. (See cut.)

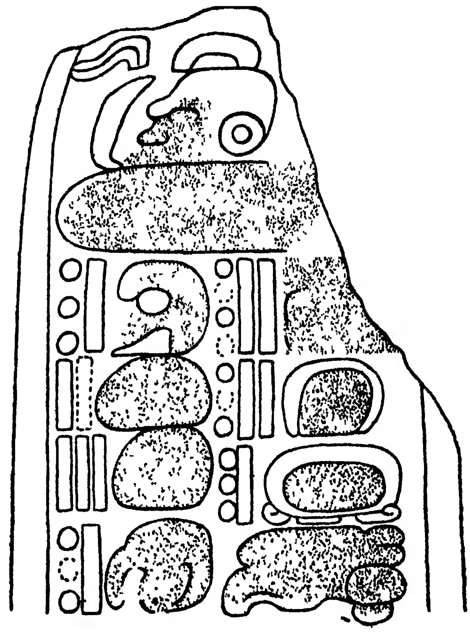

FIG. 3.—Stela 9. Uaxactun, Guatemala. The earliest monument yet reported from the Maya area (approximately 50 A. D.); and the only stela known dating from Cycle 8 of the Maya chronological era.

Stela 9 is the first and only monument yet reported which may safely be referred to Cycle 8 of the Maya chronological era, all others dating from Cycle 9 or 10; and it is therefore the earliest monument known.[1] The carving is extremely archaic in character—note the irregularity of the glyphic outlines—and the relief has suffered greatly from erosion. Fortunately the Initial Series is sufficiently preserved to decipher.

Of the 11 sculptured stelæ found, 7 have Initial Series; 1 has a Calendar Round date, and 3 are too effaced or broken to be determined. It is possible to decipher 4 of the 7 Initial Series to the day, as follows:

Name of monument.	Date in Maya chronology.			Date in Christian chronology.
Stela 2	9.16. 0. 0 0	2 Ahau.	13 Tzec.	Approx. 480 A. D.
3	9. 3 13 0. 0	2 Ahau.	13 Ceh.	Approx. 230 A. D.
7	9.19. 0. 0. 0	9 Ahau.	18 Mol.	Approx. 540 A. D.
9	8.14.10.13.15	8 Men.	8 Kayab.	Approx. 50 A. D.

Between the dates of Stelæ 9 and 7 nearly five centuries elapsed, the longest recorded occupation of any Old Empire site.

[1]The Tuxtla statuette and the Leyden plate are not included in the above statement. Although both record earlier dates than Stela 9 (8.6.2.4.17 and 8.14.3.1.12 respectively) neither is a monument, and neither, properly speaking, was found *in situ*. The Tuxtla statuette is a little figurine of nephrite, about 7 inches high, found near San Andres Tuxtla, Mexico; and the Leyden plate is a plaque of the same material and of about the same length, which was found on the Rio Graciosa near Puerto Barrios, Guatemala. Neither can be regarded as a large stone monument in the sense used here.

Approximate readings of the remaining 3 Initial Series, Stelæ 1, 5, and 6, have also been attempted. Stela 5 apparently records another Cycle 8 date, the best reading being 8.15.10.3.12, although this is open to considerable doubt. Stela 6 may certainly be referred to the Archaic Period, probably to Katuns 6, 7, 8, or 9, and Stela 1 with equal certainty to the Great Period, the best reading being 9.14.0.0.0.

The great importance of this new site lies in the number of its very early inscriptions. Stela 9 is the oldest dated monument known, and Stela 3 is the fourth oldest;[1] and it is to be expected that other early texts will be found in the vicinity. The region is new territory, having been penetrated for the first time by chicleros less than three years ago. Other important sites are known to exist beyond Uaxactun, at least one having large standing buildings and sculptured monuments.

The important bearing this site, and indeed the whole adjacent region, may have on the much-vexed question of the origin of the Maya civilization in its historical habitat, is readily apparent, and its further investigation is strongly recommended.

Van Deman, Esther B., Rome, Italy. *Research Associate in Roman Archeology.* (For previous reports see Year Books Nos. 9–14.)

Owing to the continued uncertainty concerning the conditions for archeological work in Italy, it was deemed advisable not to return to Rome before the beginning of 1916. The autumn months of 1915 were spent, therefore, in Washington, being devoted mainly to the revision for publication of the first chapters of the work on Roman concrete construction, mentioned in the previous reports. A duplicate copy of all the material on hand was prepared, also, to be left in charge of the Institution at Washington. The month of December was spent in completing the necessary arrangements for the voyage and for the resumption of the work in the field. On arrival at Gibraltar, in January, it was found inadvisable to continue the journey by sea beyond that point. In connection with the journey through southern Spain by rail, a fortnight was devoted to a general survey of the Roman remains most easily accessible at that season. The principal ancient sites visited were Seville (the ancient Hispalis, with the remains of the neighboring city of Italica), Valencia, Saguntum, and Tarragona (the ancient Tarraco).

It is clear from the remains seen, as well as from the reports concerning those farther north, that the Roman monuments in Spain are to be divided into two distinct classes. In the construction of the first class, which resembles in many particulars that of the monuments found in North Africa of the same period, the traditional building methods of the region form an important if not the con-

[1] If the doubtful reading of Stela 5 should be correct (*i. e.*, 8.15.10.3.12), it becomes the next to oldest dated monument and Stela 3 the fifth oldest.

trolling factor. The monuments of the second class, on the contrary, in their type of construction show but slightly the influence of local methods. Among the monuments of this class, those of Italica, which are assigned to the periods of Trajan and Hadrian, who were natives of this city, are of especial interest, since the methods of construction are identical, except in a few details, with those used in Italy at the same time. The monuments seen differ markedly from those of southern France in the absence of any traces of the strong Greek influence so clearly recognizable in the latter.

The spring and early summer of 1916 were devoted to the regular work of examining and classifying the remains of the ancient monuments in Rome, especially those belonging to the late republic and early empire, in which *opus quadratum*, or cut-stone masonry, appears. For the classification of these monuments a more thorough study was found necessary of the types of *opus quadratum* used in general in the various periods. An independent examination was undertaken, therefore, of the greater monuments of fixed date in which it appears, either alone or in combination with *opus cæmenticum*, with a view to establishing, if possible, some general rules concerning its use.

On account of the absence from Rome of many of the workers in the various fields of archeological research or their absorption in other necessary lines of activity, the investigation of a number of important problems along archeological and topographical lines, which was so auspiciously begun, has been for the most part suspended; but in connection with the Associate Director of the British School, Mrs. Arthur Strong, an exhaustive study of the construction and mural decoration of the so-called *pædagogium* and the adjacent building on the Palatine has been in part completed. So far as at present decided, the remains of this group of structures belong to at least four periods. Some important discoveries have been made also in the group of rooms forming the lower stories of the "Domus Tiberiana."

In connection with the work in these difficult times the courtesy and kindness of the Italian Government and of its various officials have been unfailing.

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Garrison, Fielding H., Army Medical Museum, Washington, District of Columbia. *Preparation and publication of the Index Medicus.* (For previous reports see Year Books Nos. 2–14.)

The Index Medicus for 1915 contains 1,011 pages, 300 pages less than the issue for 1914. The annual index of the same contains 170 pages, 45 pages less than that of the preceding year. The issue for 1914 contained 1,311 pages as against 1,448 pages for 1913. Thus, in the period following the outbreak of the European War, there has been a loss of some 437 pages of bibliographical material at the beginning of 1916. Germany and Italy alone, of all the combatant countries, have kept up their quota of medical periodicals, but the German periodicals have been difficult to obtain of late, under blockade conditions, and for recent numbers the Index Medicus has been largely indebted to the courtesy of the editor of the *Journal of the American Medical Association*, and to the librarians of the New York Academy of Medicine and the Boston Medical Library for loans. As soon as the outstanding mass of foreign medical literature can be obtained, it is proposed to print the titles in bulk as rapidly as possible, for the sake of continuity and completeness. Through especial courtesy of the Boston Medical Library, all the German periodicals up to March 1916 have been indexed, and this literature is contained in the double number for the months of July–August 1916.

BIOLOGY.

Morgan, T. H., Columbia University, New York, New York. *Study of the constitution of the hereditary germ-plasm in relation to heredity.*

The work carried out by T. H. Morgan, A. H. Sturtevant, and C. B. Bridges under the grant from the Carnegie Institution of Washington has been concerned with the study of the chromosomes as furnishing the mechanism of Mendelian heredity. More accurate data for the location of about 30 factors already known have been obtained; about 50 new mutant characters have been discovered, and about 40 of the factors involved have been located in their chromosomes. These data, in connection with data already on hand, give an opportunity for further study as to the nature of linkage. This phenomenon of linkage is also being more directly studied through variations caused (*a*) by environment and (*b*) by genetic factors; (*c*) through interference and (*d*) through non-disjunction and other unusual types of chromosome distribution.

Besides the main lines of work enumerated above, experiments with multiple factors and multiple allelomorphs are being carried out. These studies have both a direct and an indirect bearing on the problem of selection. This question of selection is being put to a crucial test, for there is on hand material that is suitable to give a definite answer to certain current speculations as to how selection accomplishes its results.

CHEMISTRY.

Baxter, Gregory P., Harvard University, Cambridge, Massachusetts. *Determination of atomic weights.* (For previous reports see Year Books Nos. 3–14.)

During the past year investigations upon the atomic weights of lead and zinc were continued and a new investigation upon that of tin was both begun and completed.

Mr. L. W. Parsons, after finding that lead amalgam, obtained by electrolysis, could be satisfactorily washed with ether and dried in a vacuum, analyzed fused lead chloride by electrolytic deposition of the metal in a mercury cathode. Eleven experiments with quantities of chloride varying from 5 to 19 grams yielded concordant results for the atomic weight of lead, but these were somewhat higher than the value found by Baxter, Grover, and Thorvaldson (see recent Year Books) by determination of the halogen in lead chloride and bromide. In a second series of experiments, in which a weighed quantity of metal was electrolytically transported to a mercury cathode, a small consistent gain in the product over the factors was found, amounting on an average to 0.00013 gram per gram of lead. While the cause of this gain has not yet been discovered, a suitable correction obviously should be applied to the analyses of the chloride. When this is done, the average result for the atomic weight of lead, 207.21, agrees almost exactly with that obtained by comparison of the lead halides with silver, 207.20.

Mr. J. H. Hodges applied the electrolytic method of analysis to zinc chloride. The great difficulty of preparing this salt in an anhydrous neutral condition was overcome by first dehydrating zinc bromide by fusion in a dry atmosphere containing hydrobromic-acid gas and then displacing the bromine in the fused salt by prolonged fusion in a current of dry chlorine and hydrochloric-acid gases. Five preliminary experiments, in which the metal was electrolytically deposited in a weighed mercury cathode, yielded an average value for the atomic weight of zinc of 65.38. This figure is essentially the same as that found by the determination of both bromine (Richards and Rogers) and metal (Baxter and Grose, see Year Book No. 14) in zinc bromide.

Mr. H. W. Starkweather prepared tin tetrachloride by the action of pure dry chlorine upon electrolytically purified tin. The product was purified by fractional distillation in a vacuum at low temperature and was collected in a series of sealed glass bulbs. Each bulb after being weighed was broken under dilute hydrochloric-acid solution and the metal was deposited in a weighed mercury cathode. The glass was collected separately and weighed. Sixteen concordant analyses with two series of preparations yielded the average result 118.70 for the atomic weight of tin. This confirms very closely Briscoe's value recently found by comparing the same compound of tin with silver.

Jones, Harry C., Johns Hopkins University, Baltimore, Maryland. *Continuation of investigations on the absorption spectra of solutions and on the conductivity and viscosity of electrolytes in water and non-aqueous solvents.* (For previous reports see Year Books Nos. 2–14.)

A number of problems were investigated during the year.[1]

Dr. Davis, continuing his investigations on the viscosity of cæsium salts, studied their behavior in mixed solvents containing glycerol. It had been previously shown that rubidium salts produce a phenomenal lowering of the viscosity of glycerol and its mixtures with water, the results furnishing additional confirmation of the hypothesis of Jones and Veazey to account for such negative viscosity coefficients. With cæsium salts a still greater lowering of the viscosity of the solvents used has been observed, which is to be attributed to the large atomic volume of cæsium.

Dr. Davis, with the assistance of Mr. Johnson, has also extended his studies of the conductivity and viscosity of solutions of electrolytes in formamid as a solvent. The work has necessarily progressed somewhat slowly, owing to the great difficulties encountered in the purification of the solvent. A series of nitrates and of formates have been studied. It is hoped to investigate certain representative organic acids in this solvent and finally to study the behavior of solutions in mixed solvents containing formamid. A fuller report on this work will appear subsequently.

Dr. Davis has also devised an efficient vacuum desiccator for use in the preparation of anhydrous samples of the hydrated compounds studied in non-aqueous solvents.

Dr. Hulbert and Dr. Hutchinson, using the Littrow spectroscope designed by Professor J. A. Anderson and the improved radiomicrometer built by Shaeffer and Paulus, have carried out a systematic and thorough study of the absorption coefficient of solutions for monochromatic radiation. They have determined the absorption coefficient (a) of a number of inorganic salts in water and in several of the alcohols at intervals of $20\mu\mu$ to $40\mu\mu$ throughout the region of the spectrum where the pure solvents possess appreciable absorption, $600\mu\mu$ to $1{,}300\mu\mu$ for many solutions. The values of a plotted against the corresponding wave-lengths form the absorption curve for any given solution. For each salt a series of solutions, varying in concentration from saturation to extreme dilution, was prepared and the absorption curve was drawn for each solution. From the data thus obtained, the molecular absorption coefficients (A) for the salts in the various solvents used were calculated and plotted against the gram-molecular concentrations. A careful comparative study was then made of the resulting curves.

[1]On account of the sudden death of Professor Jones in April 1916, several new lines of investigation had to be discontinued. The work reported on here was either nearly completed or well under way at the time of Professor Jones's death.

A number of improvements have been made in the apparatus, thereby enabling a single observer to make all the necessary adjustments in addition to taking the deflection readings. This proved to be a decided advantage, as it permitted Dr. Hutchinson to devote his entire time to the preparation and analysis of the various solutions used in the investigation. The cells were also somewhat modified to adapt them to the alcoholic solvents.

The results obtained by Dr. Hulbert and his co-worker indicate that, in general, the molecular absorption coefficient (A) is not a constant, but either increases or decreases with dilution and in some cases decreases to a minimum and then increases. This deviation of A from a constant value is usually comparatively small, except for some solutions at certain points in the spectrum, which were generally found to be situated at the edge of absorption bands.

The variation of A with the concentration has already been explained in a qualitative manner by previous investigators in this laboratory as due to the formation of complexes or "solvates" between the solvent and solute, but it is pointed out, as a result of this investigation, that such an explanation must be couched in mathematical terms before attempting to apply it to the interpretation of quantitative data.

Dr. Lloyd and Dr. Pardee have extended the work in absolute ethyl alcohol to include a study of the limiting conductivities of the sodium salts of organic acids in this solvent. The inability of previous investigators to obtain experimental values for the equivalent conductance of the organic acids at infinite dilution led them to undertake the problem in the hope of eventually developing Λ_0 for these acids from the data obtained from their salts.

A very accurate and convenient method for preparing the solutions of these salts in absolute alcohol has been worked out and in the subsequent measurement of their electrical conductivity a high degree of accuracy has been attained. This has been made possible by improvements in the conductivity method. Data have been obtained on sodium salts of about 30 of the organic acids; this practically covers the field of available compounds, owing to the insolubility of a great number of the acids and their salts in absolute alcohol. The conductivity values are all of the same order of magnitude, there being little difference between the aliphatic and the aromatic derivatives or between the different substituted compounds of the benzene series. Although measurements were made at as high as 20,000 liters dilution, Λ_0 was not obtained experimentally, but was calculated by extrapolation formulæ. Other investigators in this field have attempted to use the Kohlrausch formula for this purpose, although its applicability to non-aqueous solvents has been seriously questioned. The present investigators attempted to apply this formula to their data, but with such widely divergent results as to preclude its usefulness.

The formula suggested by Noyes and Johnson was finally adopted and found to give concordant results. Subsequently an approximation formula worked out by Randall was used. This formula gave Λ_0 values agreeing within the limits of accuracy of the method used and entailed much less laborious calculation than the Noyes formula.

The limiting conductivities of all the sodium salts studied have been calculated by one or the other of the above formulæ, and from them it is possible to obtain the values for the acids themselves.

Dr. Ordeman has completed the study of the relative dissociating power of free and combined water begun by him last year. Experiments carried out in this laboratory some years ago had shown that a marked physical difference exists between free and combined water, as illustrated by the different absorption power for light of solutions of hydrated and non-hydrated salts. It therefore seemed probable that a measurable difference in the dissociating power of free and combined water would exist. Carefully conducted experiments, using the conductivity method, have shown this to be highly probable. Paired isohydric solutions of hydrated and non-hydrated salts were used as solvents for the various electrolytes studied. It was found that for every pair of solutions in such solvents—the one solution of a hydrated, the other of a non-hydrated salt—the suppression of the ionization of the added salt by the anions of the solvent-solution was more prominent in the case of the hydrated solution. In other words, the increase in conductivity caused by the addition of the same amount of an added salt to each of a pair of isohydric solvent-solutions, the one non-hydrated, the other hydrated, is always greater in the non-hydrated solutions; this points to a greater dissociation in the non-hydrated than in the hydrated. Furthermore, it may be pointed out that the suppression of the ionization of the hydrated salts added was much greater than that of comparable solutions of non-hydrated salts in both isohydric solvent-solutions. From these results it seems justifiable to conclude that the water of hydration in the solutions of hydrated salts must possess less ionizing power than the uncombined water, in which case the various salts added as solutes would be dissociated to a lesser degree, the effect being greater the greater the concentration, since more combined water would then be present. The hydrated salts used as solutes are less dissociated than the other added salts, because water of hydration would then exist in both of any pair of solvent-solutions. However, the dissociation is always less in the case of the hydrated salt of any pair of solutions because of the less dissociating power of the water of hydration already present in that solution.

It should be noted, however, that the conclusions from this work can be regarded as only tentative because of its preliminary nature. Further work on the subject should be done in order to ascertain the

influence exerted by such factors as the formation of complexes in the solutions, the difference in the viscosity of the various solvent-solutions and the solutions in them, the change in the migration velocities of the anions, and the effect of the various added salts on the dielectric constants of the solvent-solutions.

Dr. Connolly, working on another phase of the same subject, has studied the different chemical activity of free and semi-combined water as illustrated by the effect on the hydrolysis of acetic anhydride.

The physical difference, already referred to, having been established by Jones and certain of his co-workers, the chemical difference was then investigated by Holmes and Jones. Their work indicated the possibility of such a difference, although the inherent errors of their method, due to the slowness of the reaction chosen and the effect of outside catalyzers, made it difficult to obtain reliable results. Consequently, a more rapid reaction was sought for—that of the hydrolysis of acetic anhydride being finally adopted. The results obtained apparently corroborate the deductions from the earlier work, although here again its preliminary nature makes further investigation advisable before drawing any definite conclusions. The hydrated salts studied, with the exception of magnesium chloride, all give results for the decomposition of the acetic anhydride greater than those of the non-hydrated ones, the latter all having a more marked hindering effect on the hydrolysis. In dilute solutions there is an appreciable acceleration of the hydrolysis of the acetic anhydride over that due to pure water alone. Sodium sulphate was found to have this effect at all dilutions. The effect of rise in temperature was also studied and found to increase the velocity of the reaction. In contrast to the other hydrated salts, magnesium chloride was found to act as do the non-hydrated salts, having a retarding effect on the hydrolysis of acetic anhydride at all dilutions.

Morse, H. N., Johns Hopkins University, Baltimore, Maryland. *Measurement of the osmotic pressure of solutions.* (For previous reports see Year Books Nos. 2–14.)

Dr. Holland, assisted by Messrs. Blocher and Minter, has been engaged, during a considerable portion of the past year, in experimental work on the manufacture and recovery of the porous cells used in the measurement of osmotic pressure. It has been emphasized in previous reports: (1) that the membrane must consist *exclusively* of minute "plugs" of the active material which are driven firmly into the mouths of the pores which open upon the *interior* wall of the cell, or, if high pressures are to be measured, into the mouths of the pores which open upon the *exterior* wall of the cell; (2) that this essential condition makes necessary: (*a*) absolute uniformity in the size of the pores, and (*b*) a degree of fineness of texture (magnitude

of pore-diameter) which will permit the more rapidly moving cation of the membrane to pass nearly through the wall of the cell from the outside, while the slower anion is only just within the interior mouths of the pores.

It has been noted, also, that the diameter of the pores must not fall below a certain minimum magnitude, since otherwise the membrane is deposited, not within the mouths of the pores, but more or less loosely upon the interior wall of the cell, where it is easily ruptured by pressure. It has been stated, further, that the allowable difference between maximum and minimum diameter of pore is not very great. The effective area of the membrane obviously depends upon the diameter of the pores in whose mouths it is deposited, and the rapidity with which the pressure will attain its maximum within a cell depends on the area of the membrane. If, therefore, the texture of the wall exceeds a certain degree of fineness—even though the membrane may be correctly located, *i. e.*, wholly within the mouths of the pores—the cell may be too "slow" for useful employment.

The foregoing statements will serve to explain the nature of some of the difficulties encountered in the manufacture of porous cells for the measurement of osmotic pressure. The limiting conditions of successful cell production were apprehended very early in the course of our work. It nevertheless required four years of experimental work to produce the first faultless porous cell.

The means by which we have been accustomed to secure the required texture of cell-wall have been briefly indicated in other reports. Unfortunately they are too elaborate and require too much special training for general use. The art of cell-making has therefore been confined, up to the present time, to the laboratory in which it originated. It is obviously desirable, however, that the porous cells which must be used in the measurement of osmotic pressure should become a commercial article, in order that the manifestations of this force may be more widely studied from the experimental side. With a view to simplifying our methods and thereby making feasible the manufacture of cells by others, we have for several years (whenever practicable) reverted to the problems of cell-making, and during the past year more seriously and persistently than at any previous time. Some progress has been made, especially in the matters of baking and glazing the cells, both of which operations have been hitherto subject to much difficulty and uncertainty—the former because of its effect in determining the size of the pores, and the latter because "*crazing*," due to difference in expansion coefficients between glaze and biscuit, can not be tolerated in osmotic cells.

Previously we have never quite succeeded in removing old and disabled membranes so as to leave the cells in perfect condition for the deposition of new ones, though the causes of the comparative

failure of our earlier efforts to "recover" cells are obscure; but during the past year Dr. Holland and his associates have overcome the difficulty by subjecting the membranes to be removed to a very slow process of electrolytic decomposition and removal by solution, and afterwards re-burning the cells.

Dr. Holland and Messrs. Blocher and Minter have carried out a complete series of measurements of the osmotic pressure of levulose at 30°. This work had been begun previous to the writing of the last report, but during the past year the earlier experiments were repeated and the measurements on all concentrations from 0.1 to 1.0 weight-normal solutions were completed. The conclusion reached is that (as in the case of dextrose) the ratio of osmotic to the calculated gas pressure of the solute is constant for all concentrations of solutions of levulose up to 1.0 weight normal. On the other hand, the hydration of the solute, which is supposed to explain the excessive pressures of both dextrose and levulose at low tenperatures, was found to be somewhat more persistent in the case of the latter than in that of the former. At 30° the ratio in question is uniformly unity for dextrose and about 1.02 for levulose.

Attempts were made during the year to resume the measurement of the osmotic pressure of cane-sugar solutions at high temperatures (above 40°), but without much success, owing in part to a recurrence of what has been called the "*Penicillium* pest."

At somewhat elevated temperatures cane sugar soon begins to invert in the cells. If the cell "works rapidly," *i. e.*, if the osmotic pressure rises quickly to a maximum, a measurement may be secured before the inversion reaches a significant magnitude. It is therefore impracticable to employ with cane sugar at elevated temperatures any but fresh membranes of large area. This slow inversion, which is observed in cells at the higher temperatures, is perhaps promoted, if not caused, by the presence in the solutions of a minute quantity of the membrane material; for it has been observed that portions of the same solutions, maintained outside of the cells at the same temperatures, and for the same length of time, do not, if properly protected, exhibit inversion.

The liability to "penicillium infection" is always impending, and the presence of the spores in the air is one of the great obstacles in the way of the measurement of osmotic pressure. These penicillia—said by our experts who have studied them to some extent to be of various "strains"—attack the membranes with great voracity, probably because of their nitrogen content, and unless they are quickly checked they soon destroy the membranes. Our methods of avoiding infection and of exterminating *Penicillium* when, in spite of our elaborate precautions, it has lodged in the cells and baths, have been described elsewhere. The complete eradication of the pest usually

requires several months, and measurements made in infected cells are not regarded as reliable. An interesting phenomenon observed in connection with infected cells whose membranes have not yet become "leaky" is the development of abnormally high pressures. In fact, the development of too high pressures is one of the earliest symptoms of infection. The explanation is, of course, that the products of *Penicillium* activity serve to increase the concentration of the solutions.

It was stated in the report of last year that it had always appeared important to the writer and to those associated with him to extend the scope of their work so as to include a simultaneous determination of the vapor-tension of the solutions under investigation; also that Doctors Frazer and Lovelace had succeeded in developing a practicable method of great precision for this purpose. Preliminary accounts of their method have been published in the *Journal of the American Chemical Society*. During the past year, assisted by Messrs. Sease and Rodgers, they have investigated the vapor-tension of the following solutions: (*a*) of mannite from 0.1 to 1.0 weight normal; (*b*) of sodium chloride from 0.1 to 3.0 weight-normal concentration.

The most striking development of the year has been the success attained by Dr. Frazer, assisted by Mr. Myrick, in the measurement of very high osmotic pressures. The method in the form in which it has been employed hitherto is satisfactory up to perhaps 60 atmospheres. Under greater pressures the cells frequently burst. In order to overcome this difficulty Dr. Frazer has reversed the method of formation in such a manner as to deposit the membrane on the exterior instead of the interior surface of the cell-wall. The cell is placed within a bronze container of the necessary strength. The solution occupies the space between the two, while the porous cell is filled with water which is in communication with a supply of water under atmospheric pressure. The manometer is attached to the bronze container. With such an arrangement pressures up to 125 atmospheres have been measured satisfactorily.

For pressures above 125 atmospheres, glass manometers no longer suffice, and for such Dr. Frazer has constructed a device for measuring osmotic pressure by means of the effect of pressure upon the conductivity of certain alloys. It consists, essentially, of a combination of the Johnston modification of the Bridgman resistance-gage with the Corey-Foster bridge and high-sensitivity galvanometer for the measurement of resistance changes. This equipment, over a range of 50 atmospheres, is sensitive to about 0.02 atmosphere, and over a range of 500 atmospheres the one in use has a sensitivity of about 0.05 atmosphere. The gage-readings are thought to be correct to about 0.2 atmosphere. With the arrangement in question Dr. Frazer and Mr. Myrick have measured osmotic pressures up to 270 atmospheres.

It is with great regret that the writer announces the retirement of Dr. W. W. Holland, after nine years of devoted and effective service. Much of the success of the investigation has been due to his resourcefulness, skill in difficult manipulation, tireless energy, and unconquerable optimism.

Noyes, Arthur A., Massachusetts Institute of Technology, Cambridge, Massachusetts. *Researches upon the properties of solutions in relation to the ionic theory.* (For previous reports see Year Books Nos. 2–14.)

During the past year the researches referred to in previous reports, on the electromotive forces of concentration-cells and on the equilibrium-relations of oxidizing and reducing agents, have been continued.

Dr. J. H. Ellis and Mr. F. W. Hall continued the investigation of the electromotive force of cells of the type H_2, HCl, Hg_2Cl_2 + Hg, with the purpose of determining the magnitude of the deviations from the laws of perfect solutions which largely ionized solutes exhibit; and a description of this work has been published. Difficulties were encountered in the case of solutions more dilute than 0.1 normal, but these have now been overcome by using a silver-chloride silver electrode in place of the calomel electrode, and accurate results have been obtained down to 0.003 normal.

These researches have shown a remarkable divergence between the so-called ionization-coefficient of the hydrochloric acid (as derived kinetically in the usual way from electrical conductivity measurements) and its ion activity-coefficient as derived thermodynamically from these electromotive-force measurements. This is shown by the following table of values of the two quantities:

Molal concentration..... ..	0 001	0.01	0 1	0.3	0 5	1.0	2 0	4.5
Ionization-coefficient	0 99	0 97	0.92	0 90	0 89	0.84		... .
Ionactivity-coefficient ...	0 99	0 93	0 82	0 78	0 77	0.84	1 06	2.25

Dr. E. W. Wescott has completed the research on the equilibrium conditions in aqueous solution of the reaction $PbCl_2$ (solid) + Cl_2 (gas) + $H^+Cl^- = H^+PbCl_5^-$. The results, which furnish a measure of the oxidation tendency of plumbous to plumbic lead, will soon be published.

A new line of investigation on the water-vapor-pressure of salt hydrates (such as $CuSO_45H_2O$, $Na_2HPO_412H_2O$) has been undertaken and has been actively prosecuted during the past year with the aid of several assistants. The work has thus far been directed mainly towards the development of satisfactory experimental methods, to replace the inexact time-consuming method commonly employed of allowing the vapor-pressure of the hydrate to establish itself in an evacuated tensimeter. Two such methods have been worked out. One of these consists in placing the salt hydrate in one pan of a small

balance suspended in a large glass desiccator containing dilute sulphuric acid and varying the concentration of this acid, whose water-vapor-pressure is well known, till the salt-hydrate neither loses nor gains weight. Another method consists in shaking the salt-hydrate with an organic solvent (amyl alcohol) till it becomes saturated with water from the hydrate and then determining the water-content of the solvent, to which corresponds a certain known water-vapor-pressure.

A research has also been started by Dr. W. N. Lacey on the hydrolysis at 100° of ammonium salts of very weak acids, such as carbonic acid, with the view of extending our knowledge of the ionization of such acids (which is confined to the neighborhood of the room temperature) to higher temperatures.

Richards, Theodore W., Harvard University, Cambridge, Massachusetts. *Continuation of exact investigations of atomic weights and other physico-chemical properties of elements and simple compounds.* (For previous reports see Year Books Nos. 2–14.)

The following investigations have been conducted during the past academic year with the assistance of this grant, employing also permanent apparatus purchased with previous grants as well as with funds of the university.

1. The Atomic Weight of Isotopic Lead

This research, conducted with the help of Dr. Charles Wadsworth 3d and Norris F. Hall, was a continuation of that begun three years ago with the assistance of Dr. Lembert.[1] The acquisition of a large quantity of Australian isotopic lead, through the kindness of Mr. Bubb of the Radium Hill Company, and the cooperation of Mr. S. Radcliff, made possible a valuable extension of the work. This sample, because of its large quantity, could be more thoroughly freed from common impurities than the smaller samples previously employed; and it was recrystallized as nitrate and chloride until its ultra-violet spectrum (photographed by Professor Baxter) and its visible spectrum as far as wave-length 7600 (photographed on orthochromatic plates and studied visually in a Hilger spectrometer) showed no trace of any line foreign to ordinary lead prepared by Baxter in the highest degree of purity. Nevertheless, the atomic weight of this substance was found to be as low as 206.35 (instead of 207.19) and this low value was not altered by continued purification, as far as we have yet been able to pursue it. Another especially valuable sample, obtained from pure selected crystals of Norwegian cleveite through the kindness of Dr. Ellen Gleditsch of Kristiania, gave the atomic weight 206.085, the lowest yet found by us, and almost as low as the lowest found by Dr. O. Hönigschmid, who has confirmed our results.

[1] See previous Year Books

One is disposed to conclude that pure "iso"-lead (assumed to come from the decomposition of uranium and radium) must have an atomic weight very near this last value, and that the Australian "iso"-lead consists of this same substance mixed with about one-third of its weight of ordinary lead. The mixture has not yet been separated by any means as yet employed. Isotopic lead is clearly very similar to ordinary lead in most of its chemical properties. This research has just been published.

The following table contains the experimental data and results.

The atomic weight of isotopic lead.

Sample ore	Locality.	Corrected weight.	Corrected weight added	Ratio $PbCl_2$:Ag.	Atomic weight.
1. Carnotite	Australia	4 64010	3 61118	1 28493	206 318
2. Carnotite	Australia	5 35517	4 16711	1 28512	206 359
3. Carnotite	Australia	6 15608	4 79072	1 28500	206 334
4. Carnotite	Australia	4 14770	3 22748	1 28512	206 359
				Average	206 342
5. Carnotite	U. S. A	5 31585	4 12670	1 28816	207 015
6. Carnotite	U. S. A	4 65899	3 61707	1 28806	206 994
				Average	207 004
7. Bröggerite	Norway	4 29104	3 34187	1 28402	206 122
8. Cleveite	Norway	3 92736	3 05913	1 28382	206 079
9. Cleveite	Norway	4 45270	3 46818	1 28387	206 090
				Average	206 085

2. The Density of Isotopic Lead.

This research also was conducted by Dr. Charles Wadsworth 3d. The Australian mixture and the Norwegian pure sample just described were reduced to the metallic state and were compared with pure ordinary lead prepared in exactly the same way. Parallel determinations gave as the respective densities of the ordinary lead, the Australian mixture, and the pure Norwegian "iso"-lead, the values 11.337, 11.289, 11.273. These numbers are very nearly proportional to the atomic weights, "iso"-lead having a density unquestionably less than ordinary lead, and each having almost exactly the same atomic volume, 18.28. The results have already been published.

3. The Compressibility of Casein and Other Substances of Physiological Importance.

This subject was studied experimentally by Sven Palitszch (of the Carlsberg Laboratory of Copenhagen, Scandinavian-American scholar) with the help of apparatus already described. Especial attention was given to the comparison of the compressibilities of the solids with those of concentrated solutions and suspensions of the substances concerned. The results will soon be ready for publication.

4. The Effect of Pressure on the Solubility of Sodium Sulphate.

Continuing the work conducted during the previous year by Dr. Sill, we sought by this investigation to study with great precision the thermodynamic relationships involved in a typical case. The experimentation was conducted by Otto Maass (1851 exhibition scholar from Montreal). The results were interesting, including not only the direct determination of the quantity in question, but also the change of volume on solution, the heat of solution, and other data concerned in the thermodynamic relationship.

5. Surface Tension of Carbon Compounds.

In the Year Book of last year the work done by Mr. L. B. Coombs with the support of the Institution was briefly reviewed; this work has since been published. The present research was a continuation of this, in the hands of Emmett K. Carver. Part of the preliminary work was repeated and verified, new results on other substances were obtained, and especial attention was given to the vexed questions concerning the shapes of the meniscus and the other minor corrections. This research will be continued during the coming winter.

6 The Silver Coulometer

Norris F. Hall continued the study of the irregularities of this instrument, investigating the causes of inclusion of mother liquor, the influence of various impurities, and especially the effect of varying the state of the cathode. The discovery of the Bureau of Standards that platinum black upon the surface of the cathode diminishes the amount of the deposited silver was confirmed; it was shown that this source of error could not have greatly affected the earlier Harvard data found by Dr. Anderegg, but that it was probably large enough to render doubtful some of the more subtle conclusions drawn from those results. These matters are to receive further attention in the near future, and a fuller report may well be deferred.

7. The Electromotive Forces Between Different Concentrations of Liquid Sodium Amalgams.

Conducted by Dr. J. B. Conant, this research was a continuation of similar work of this kind described in previous Year Books and in Publications 56 and 118. Sodium was chosen because of its univalent nature and its great heat of amalgamation. The high chemical activity of these amalgams necessitated many modifications of apparatus too complex to be described here, and interfered with the certainty of the results; but there seems to be no doubt that sodium amalgams show the same phenomena as thallium amalgams in greatly exaggerated degree, as had been expected.

Sherman, H. C., Columbia University, New York, New York. *Continuation of the chemical investigation of the amylases.* (For previous reports see Year Books Nos. 11–14.)

During the past year the investigations, referred to in previous reports, upon the chemical properties of three typical amylases of widely different biological origin, have been continued, chiefly through detailed quantitative studies of the reactions induced by these enzymes and of the conditions most favorable to their action.

In the study of pancreatic amylase attention has been directed especially to the determination of the optimum hydrogen ion concentration and to the measurement of proteolytic activity. Determination of the exact alkalinity at which this enzyme shows its greatest amylolytic power is especially difficult because of the extreme sensitiveness and instability of its solutions. The results thus far obtained show that the region of optimum activity is not so sharply limited as in the case of malt amylase reported last year. The greatest activity of the malt enzyme, whether activated by strong or weak acid or by acid salt, was found always at P_H^+ 4.4 (within limits of experimental error of measurement of hydrogen-ion concentration); but the pancreatic amylase in solutions activated by chloride and phosphate shows optimum activity (within limits of error in measuring the diastatic power) throughout the range of P_H^+ 7.0 to 7.6. Using carbonate instead of phosphate as alkaline activator, the quantities resulting in optimum activity have been determined experimentally and the hydrogen ion concentrations of these solutions are now being measured. In connection with these figures we would note that highly purified water, such as was used in these experiments, or water containing only a minimum addition of neutral salt, showed (as pointed out by Fales and Nelson and repeatedly confirmed in our work) an index of 5.6 to 6.2.

The systematic investigation of proteolytic activity in our pancreatic amylase preparations necessitated first a careful study and adaptation of several methods for detecting and measuring proteolysis. This study has now been completed and the data prepared for publication. While space does not permit discussion of these results, it may be noted that the quantitative methods, and especially those based upon the measurement of the total nitrogen or amino nitrogen of digestion products, which are best adapted on theoretical grounds to the purposes of our investigation, can be made quite as delicate as the merely qualitative tests for products of proteolytic activity.

Using the quantitative methods thus developed, we have carried on during the year a somewhat extended series of measurements of the proteolytic activity, previously noted as an unexpected property of our purified pancreatic amylase preparations. Whether measured

by total nitrogen, amino nitrogen, or acidity of digestion products, by increased conductivity of substrate solution, or by the polarimetric method, the best pancreatic amylase preparations show a strikingly high and consistent proteolytic activity of the tryptic type, fully equal in fact to that of the most active commercial trypsin which has come to our notice, though not so high as in certain pancreatic enzyme preparations made in the laboratory. Our best malt amylase preparations show no proteolytic activity, although tested through a wide range of hydrogen ion concentrations. This and the fact that the optimum amylolytic and proteolytic activities of malt extract are shown at different degrees of acidity are consistent with the general view that malt amylase and malt protease are independent substances, whereas in the case of purified pancreatic amylase we have the two enzymic activities concentrated in the same product and showing optimum activity at nearly the same degree of alkalinity. These results, which are now ready for publication, give added weight to the problem of the exact nature of the relationship which exists between the amylolytic and proteolytic properties of our purified amylase preparations, upon which it is hoped that further light may be obtained through purification experiments directed to the concentration of proteolytic power.

The course of the hydrolysis of starch to maltose under the influence of purified malt amylase has been studied, with quantitative determinations of the velocity constant at different stages of the hydrolysis and under varying conditions of activation and concentration. In some cases the experiments have been performed on different starch substrates—the soluble starch ordinarily used, starch pastes prepared by heating in the autoclave, and the α and β fractions of starch as separated by the method recently developed in this laboratory. In this connection it has been found that the "delayed iodine end-point," previously noted as a difficulty encountered in studying the amyloclastic action of purified malt amylase upon soluble starch, occurs also with each of the new substrates and is therefore to be regarded not so much as a defect of the method but rather as a characteristic property of this enzyme. The comparison of the different starch preparations as substrates also shows that soluble starch is well adapted to this purpose and that its use leads to conservative estimates of the diastatic powers of purified amylase preparations.

The experiments upon the purification of the amylase of *Aspergillus oryzæ* and the comparison of its chemical properties with those of pancreatic and malt amylases are being continued.

The efficient work of those who have collaborated in these investigations, whether as research assistants or volunteers, is gratefully acknowledged.

GEOLOGY.

Chamberlin, T. C., University of Chicago, Chicago, Illinois. *Study of fundamental problems of geology.* (For previous reports see Year Books Nos. 2–14.)

A portion of the year was given to the preparation and publication of a small book on The Origin of the Earth, in which an effort was made to bring together, in a form as well suited to the needs of the general scientific reader as the nature of the subject would permit, the main results of the inquiries set forth in a less connected and more technical way in Year Books Nos. 3–14, together with such accretions as had gathered about these. There were included some notable extension of the details of the planetesimal hypothesis and some new matter relative to the application of the planetesimal view to terrestrial problems. Among these was a fuller statement of the origin and extent of the atmosphere and of the dynamic organization of its outer portion as deducted from the kinetic theory of gases. This embraced deductions relative to the mutual interchanges of atmospheres.

The most notable addition to matter previously published related to the juvenile shaping of the earth as deduced from its progressive growth under the conditions of rotation, tidal action, and periodic shrinkage. The progressive shaping of the earth, as thus set forth, carries not only a tentative explanation of the great physiographic features of the earth, but a new view of the mode by which approximate isostatic adjustment is accomplished. The initiation and the early results of this line of study were reported in Year Book No. 12.

The book issued also included some notable extension of the application of previous results to the study of stress-conditions within the earth, with indications of the bearing of these upon the mutations and changes of state of the interior, as also upon igneous extrusion and upon the rigidity of the earth.

The possible habitat of the earliest life and the specific geologic environment under which the physico-chemical syntheses leading up to organic action found conditions suited to their progressive action were also set forth in a final chapter.

As the study of the genesis of the earth was undertaken in response to a feeling that there was urgent need for a basis of interpretation of early geologic phenomena more closely in accord with the geologic record than was offered by the theories of genesis then current, and as a tentative basis of this kind seems to have been found in the planetesimal hypothesis, and as this hypothesis should go through a prolonged test of its working qualities before a final judgment is formed, it has seemed best to rest the cosmogonic inquiry at this stage and turn to the new aspects of geologic problems that arise under it. It has, however, seemed worth while to gather up such incidental cosmogonic suggestions as have arisen in the course of the inquiry, even

though they may have little direct bearing on the specific problem of the genesis of the earth. A considerable part of the rest of the year has been spent in putting this matter in order. Incidental to these two chief lines of work, some progress has been made on the lines of geologic inquiry that seem most to invite future attention—the major dynamics of earth-shaping and the climates of the geologic ages.

Vaughan, T. Wayland, U. S. Geological Survey, Washington, District of Columbia. *Study of the stratigraphic geology and of the fossil corals and associated organisms in several of the smaller West Indian Islands.* (For previous report see Year Book No. 14.)

During the year from October 1, 1915, to September 30, 1916, most of the time which could be spared from my fixed duties on the U. S. Geological Survey was devoted to the completion of three papers in press as parts of Publication No. 213 of the Carnegie Institution of Washington. However, the short papers listed on page 38 of this Year Book were published and the following manuscripts were written:

An outline of the geotectonic provinces and of the geologic history of the perimeters of the Gulf of Mexico and of the Caribbean Sea.

An outline of the physiographic features and of the stratigraphic geology of Cuba.

A summary of the geologic history of the coral faunas of the southeastern United States, the West Indies, and Central America during Tertiary and Quaternary time is included in a paper entitled "A reef-coral fauna from Carrizo Creek, Imperial County, California, and its significance," in press as Professional Paper 98–T of the U. S. Geological Survey. Collections made during February and March 1914, in Antigua, St. Bartholomew, and Anguilla were utilized in the preparation of this paper. The reports on the stratigraphic geology, the paleontology, and the geologic history of Cuba and of the Lesser Antilles, are almost ready for press. There is no need to repeat information contained in the progress reports published in Year Book No. 13, pages 358–360, and Year Book No. 14, pages 368–373.

HISTORY.

Andrews, Charles M., Yale University, New Haven, Connecticut. *Preparation of a general history of the colonies in America.* (For previous report see Year Book No. 14.)

Since September 1, 1915, I have continued my investigations as follows: During September I worked in the New York Public Library and the New York Historical Society; during the academic term from October 1 to February 1, 1916, I spent nearly all the week-ends in the Connecticut Archives; beginning February 1 and continuing until September 1, I visited Washington, Richmond, Raleigh, Wilmington, Charleston, and Boston, searching for colonial manuscripts. The bulk of the material gathered will not be used for some time, but one or two brief papers are in preparation as by-products of the investigation.

Osgood, Herbert L., Columbia University, New York. *Completion of an institutional history of the American colonies during the period of the French wars.* (For previous reports see Year Books Nos. 11–14.)

Work on the "Institutional History of the American Colonies" has progressed steadily during the year, and comparative study of the thirteen colonies is approaching completion. New Jersey and Pennsylvania are the only colonies upon which much remains to be done. Dr. Elmer B. Russell, my assistant, has completed the examination of manuscript and printed materials in all of the Southern States and in Pennsylvania and has also gone through a large collection of pamphlets in the New York Public Library. The collection of material in this country will soon be completed. Between forty and fifty chapters have been written, either wholly or in part, but it will not be possible to publish anything until the British side of the subject is more fully investigated.

LITERATURE.

Bergen, Henry, Brooklyn, New York. *Research Associate in Early English Literature.* (For previous reports see Year Books Nos. 11–14.)

During 1916 I have brought down the revision of the Glossary of Lydgate's Troy Book to the point reached by the latest part issued of the Oxford Dictionary (this will probably be half-way through the letter U) and have completed the final revision for the press of the text of Lydgate's Fall of Princes. I first intended the Troy Book Glossary to be, like all the glossaries appended to works issued by the Early English Text Society—simply a list of the more difficult and unusual words, together with their definitions. As the Oxford Dictionary was well under way when I began to collect the material, I naturally turned to it as my chief source of information; but during the course of this early work I found that several words in the Troy Book were not represented in the dictionary at all; that others, having been cited from the comparatively late and inaccurate printed editions were wrongly classified, and it turned out on further investigation that certain constructions and many specific uses of words employed by Lydgate in his Troy Book were registered in the dictionary as having made their earliest documented appearance in the language in texts which in many instances had been written one or two centuries after Lydgate's death. For this reason I thought it would be well to broaden the scope of the Glossary and to include in it all the words used by Lydgate in the Troy Book, together with as many examples of their different meanings and constructions as I could conveniently gather, in the hope that in addition to furnishing material for the study of the language of the period, it might serve as a foundation for a complete Lydgate glossary and perhaps prove to be of some value to the editors of the Oxford Dictionary when the time came for issuing a supplementary volume. This necessitated a

complete recasting of my work, a fresh collecting of material, as well as a considerable delay in consequence of having to wait for the publication of the successive parts of the dictionary, which is now fortunately almost completed. The delay has caused less inconvenience than might have been expected, for the reason that since 1912 I have been working on the Fall of Princes and have consequently been able to turn from one task to the other as circumstances permitted.

MATHEMATICS.

Morley, Frank, Johns Hopkins University, Baltimore, Maryland. *Application of Cremona groups to the solution of algebraic equations.* (For previous reports see Year Books Nos. 9–14.)

The second paper embodying Professor Coble's investigation of point sets and Cremona groups will appear in the October number of the *Transactions of the American Mathematical Society.* An abstract of this paper was given in the *Proceedings of the National Academy of Sciences*, volume 2, April 1916.

The third part has been submitted for publication in the *Transactions.* It deals with the determination of the lines on a cubic surface. The treatment differs from that of Klein and Burkhardt in three important points: (1) the transition from the given surface to the collineation group arising from the theta functions is accomplished through the intervention of linear systems of irrational invariants of the surface; (2) these groups are introduced by means of a certain normal form of the hyperelliptic surface analogous to the normal form of the elliptic curve, the line being replaced by a Kümmer surface; (3) the most convenient final problem is the form problem of the Burkhardt group, for which a solution (hitherto lacking) is found.

In the entire discussion no use is made of an equation of degree 27 or other resolvent equation.

A number of questions suggested by the above, which in a sense are grouped by their connection with the properties of "elliptic quintics in δ_4," are considered under that title in a paper to be submitted to the American Journal.

The attempt to connect the general theta functions with point sets and thereby to get a geometric grip on their properties has been successful up to a certain point. The general tactical correspondence between the two is established in the article, "An isomorphism between theta characteristics and the $(2p + 2)$-point" which appeared in the *Annals of Mathematics*, series 2, volume 17, March 1916. Here, also, when $p = 3$ theta-relations are set forth which vitalize the isomorphism. Similar relations have been obtained for $p = 4$. There remains the problem of obtaining these relations for any value of p and of identifying the theta moduli with the irrational invariants of the $(2p + 2)$-point.

MATHEMATICAL PHYSICS.

Moulton, F. R., University of Chicago, Chicago, Illinois. *Investigations in cosmogony and celestial mechanics.* (For previous reports see Year Books Nos. 4, 5, 8–14.)

The investigations of the year which are as yet unpublished are:

(1) *Computations of periodic orbits.*—Contrary to the report of a year ago, there turned out to be one outstanding critical case in periodic orbits which was needed to complete the work which has been under way a number of years. It proved to be one of great difficulty and cost eight months' work. It is now believed to be complete.

(2) *Functions of infinitely many variables.*—The work on infinite systems of equations, reported on last year, has been greatly extended in a number of directions. An application of particular interest is the dynamics of an infinite universe in which there are galaxies, each composed of a finite number of stars; super-galaxies of the first order, each composed of a finite number of galaxies separated by distances which are great compared to their dimensions; super-galaxies of the second order, each composed of a finite number of galaxies of the first order; and third-order and still higher-order super-galaxies, without limit, similarly composed of finite numbers of super-galaxies of the next orders lower. Such an organization is strictly in harmony with observational experience; it is analogous to the organization from electrons through atoms and molecules up to our galaxy; it contains an infinite amount of matter and an infinite amount of energy; it may have existed roughly in its present condition for an infinite time in the past, and may continue to exist without becoming cold and lifeless for an infinite time in the future. Moreover, it has been shown that the dynamical properties of such an infinite universe are the same as those of the visible universe. This result is by no means trivial, for it has not been true in some very important suggestions for infinite systems hitherto made.

(3) *Evolution of stars.*—The consideration of the problem of the evolution of the stars has led to establishing a number of laws of the general type of Lane's law. Among these results are:

(*a*) The absolute temperatures of stars of equal volumes of the same monotomic gases are proportional to their masses.

(*b*) The absolute temperatures of stars of the same density and monotomic gases are proportional to the squares of their radii.

(*c*) The absolute temperatures of monotomic gaseous stars are proportional to the cube roots of the products of the squares of their masses and their respective densities. All these laws hold irrespective of the source of the heat of stars.

(*d*) Under the assumptions that the heat of stars is entirely produced by their contraction, and that their rates of radiation at different temperatures satisfy Stefan's law, it is found that the rate of diminution of the radius of a star is proportional to the square of its mass.

(*e*) Under the same hypotheses, the rate of increase of density of a star is proportional to the cube root of the fifth power of its mass.

METEOROLOGY.

Bjerknes, V., University of Leipzig, Leipzig, Germany. *Preparation of a work on the application of the methods of hydrodynamics and thermodynamics to practical meteorology and hydrography.* (For previous reports see Year Books Nos. 5–14.)

Dr. Th. Hesselberg left the service of the Carnegie Institution of Washington at the end of the year 1915, having been appointed Director of the Norwegian Meteorological Institute. He has been succeeded by Mr. Holtsmark.

Previous reports have referred to what we have called frictional resistance to atmospheric motions. The observations having given the change of motion during a certain time as well as some of the forces producing this change (pressure-gradient, deviating force of the earth's rotation), the problem in its most general form was this: to find the unknown force which, added to the known forces, produces the known change of motion. This unknown force is of a complex nature, but is, for the sake of brevity, referred to simply as friction. It has turned out to be possible to obtain fairly constant average values of this force (*cf.* previous reports). These average values being found, we have tried to treat the reverse problem: to determine the change of motion during a short interval of time (3 hours), all forces, including friction, being considered as known. As for this problem we should want the true local and momentary values of the friction, but we know only certain average values, we do not claim that the solution must necessarily succeed; but it is desirable to try it as the most direct way of obtaining further insight into the nature of "atmospheric friction."

A great difficulty, however, in this case is the incompleteness of meteorological data. We have begun with observations from the United States of America, kindly copied for us by the U. S. Weather Bureau. They give the meteorological elements at all stations for every hour during the following periods: 1905, January 1, 2, 3; 1905, November 27, 28, 29; 1911, November 10, 11, 12.

In order to avoid complications due to the topography of the land, we chose for our investigations the region limited on the west by the Rocky Mountains, on the east by the Appalachian Mountains, on the north by Canada, and on the south by the Gulf of Mexico.

The first attempts led to apparently absurd results, showing that the local and momentary values of the friction could differ enormously from the average values. More detailed determinations of the friction for the defined region were therefore sought, and a chart of friction was drawn, derived only from winter observations. In order to realize as far as possible the conditions corresponding to average friction, and in order to reduce at the same time the effect of the errors of observation, the observed winds and the observed gradients were averaged, on the one hand for periods of 3 hours, on the other hand for areas of 250 square kilometers. We obtained in this way charts

of wind and charts of pressure of a much simpler description than the original ones. But in spite of these simplifications, no satisfactory correspondence could be obtained between the calculated changes of motion and those obtained from the observations, showing thus that the irregularities of friction are not sufficiently smoothed out by this averaging for short intervals of time and for small areas.

These investigations are not yet finished. Especially will it be important to take them up for Europe. Here the common meteorological observations are not so satisfactory. But we have the opportunity of choosing the days of the international meteorological ascents, and thus to study the phenomena on the base of a tolerably complete knowledge of the motion of the higher atmospheric strata.

One of the possible explanations of the difficulties met with in these investigations on friction may be motions of the type of waves or of oscillations. The theory of atmospheric waves has therefore been made the subject of further investigations. A first paper, giving the fundamental equations of these waves, has been published (see list of publications, p. 30), and two further papers giving special integrations are in preparation.

In order to apply the laws of thermodynamics to atmospheric processes, complete tables have been worked out for calculating energy and entropy of moist air. Parallel with this practical thermodynamic work, our theoretical investigations have led to important results concerning the atmosphere and the sea considered as heat engines (see list of publications, p. 30).

A mixed dynamic and thermodynamic investigation concerning the trade-winds has been taken up, based on observations collected in the region of the north Atlantic trade-wind by Rotch, Teisserenc de Bort, and Hergesell. Charts have been drawn representing average temperature, average pressure, and average horizontal motion in all levels up to the height of 10 km. By use of the equation of continuity the corresponding vertical motion has been derived. On the basis of these data a thermodynamic discussion of the trade-wind will be attempted.

In connection with the above special investigations on dynamics and thermodynamics of the atmosphere, the preparation of volume III, "Dynamics," of the work "Dynamical Meteorology and Hydrography" has been continued.

NUTRITION.

Osborne, T. B., and L. B. Mendel, New Haven, Connecticut. *Continuation and extension of work on vegetable proteins.* (For previous reports see Year Books Nos. 3–14.)

Our recent experiments corroborate the belief that different proteins have unlike physiological values in nutrition. The most important method of demonstrating this determines the minimum of each protein required for nutritive equilibrium. Earlier experience indicated differences in the relative nutrient efficiency of different proteins—inequalities which formerly were not taken into account in the practice of feeding. Our experiments were limited by the quantitative inequalities of the food ingested by the experimental animals.

Further maintenance experiments consequently were undertaken, in which the daily food intake was limited to a fixed quantity, the protein concentration being adjusted until no essential gain or loss of body-weight ensued. The absolute intake of the added protein per gram of animal per week established a protein minimum for maintenance in each experiment. Comparisons have been made in this way at different levels of body-weight, so that the factor of size might be taken into account. The total energy intake was sufficiently liberal to permit considerable growth had the supply of protein been sufficient. In addition to the adequacy of the fats and carbohydrates, the inorganic constituents as well as the food "accessories" were fed in absolutely the same amount daily. The added protein thus represented the only important variable in the experiments which were in all cases sufficiently long to justify a decision regarding a permanent gain or loss of body-weight. The results fully justify our earlier conclusions, particularly regarding the nutritive superiority of lactalbumin.

It may be expected that where growth is involved the inequalities between the different proteins would more readily manifest themselves. The difficulties of ascertaining the protein minimum for growth are decidedly greater than for maintenance; for by growing, the animal alters its needs from day to day so that it is not easy to establish a unit of comparison. It is then essential to make comparative studies of growth under conditions in which the total caloric intake, the absolute amount of protein eaten, the quantities of inorganic salts, or amount of "food accessories," are strictly comparable.

In one series of trials the experiments were varied in respect to the protein of the diet. The food intake was so adjusted that in any event there would be no unnecessary surplus of food ingested. The rats—all males—were of approximately the same body-weight (45 to 50 gm.) at the beginning of the experiment. The trials were begun with lactalbumin, edestin, and casein, the latter alone or with additions of cystine or alanine. The period of comparison in this series

lasted 77 days. The animals consumed practically all of the food offered, so that the food intake of each scarcely varied more than 2 or 3 gm. We thus found that the average total gain in 11 weeks upon the diet containing 14.8 per cent of lactalbumin was 122 gm., in contrast with a gain of 105 gm. and 95 gm. on similar diets containing 16.2 per cent of casein and 16.7 per cent of edestin respectively. With 19.8 per cent of casein or 20.5 per cent of edestin the total gains were below those obtained on the same daily intake of food containing 9.9 per cent of lactalbumin.

Since the food intakes were strictly comparable and the trials extended over long periods, the superior nutritive efficiency of lactalbumin is thus demonstrated. Incidentally, inasmuch as the animals all received the same amount of food on corresponding days, the rapidly growing ones, fed with the superior growth-promoting proteins, were actually at a disadvantage.

When casein was supplemented by cystine, so as to make the quantity of this amino-acid equivalent to 3 per cent of the protein, a smaller quantity of casein sufficed for a given gain in weight; thus, whereas on a diet containing 8 per cent of casein the total gain during 11 weeks was 71 gm., in contrast with 77 gm. gained on an otherwise comparable food containing 8 per cent of lactalbumin, the addition of cystine to an 8 per cent casein diet led to growth equal, while the experiments lasted, to that on the 8 per cent lactalbumin diet. It is unlikely that this result is due to a stimulating action of the cystine; for the substitution of alanine, under precisely similar conditions, failed to induce more rapid growth.

The only strict basis for comparison is afforded by experiments in which the animals receive the *same amount of food* during the *same period of time* and make the *same gain in weight.* In order to eliminate, as far as possible, inequalities in the rate of growth of different individuals and also to be certain that no protein would be "wasted" by feeding more than the individual could actually utilize in the metabolism of growth, the concentration of protein in the rations of the present series was lowered so that with a sufficient total energy intake, the protein furnished was insufficient to permit average normal growth. For these experiments a diet containing 8 per cent of lactalbumin was taken as a standard with which edestin and casein (alone or with cystine or alanine) could be compared. Under these conditions of nutrition, identical except as regards the quantity of protein eaten, lactalbumin proved to be superior to both casein and edestin. Thus there were required to produce the same gain in body-weight 12 per cent of casein (50 per cent more than of lactalbumin) and 15 per cent of edestin (nearly 90 per cent more). With the lower concentrations of casein or edestin the rate of growth was in every case noticeably behind that produced by the standard lactalbumin food. In this series, likewise, the addition of cystine, equiva-

lent to 3 per cent of the casein used, effected considerable economy, as shown in the table below. We thus see that the addition of cystine rendered the casein so much more efficient for growth that, on the average, 18 per cent less protein produced 12.5 per cent more growth.

Protein in food.	No. of experiments.	Total gain in weight.	Food intake.	Days.	Protein intake.
		gm.	*gm.*		*gm.*
Casein 10 per cent.	3	64	385	56	38 5
Casein 8 per cent + cystine. . .	3	72	388	56	31.0

We have published additional experiments with tryptophane and lysine which afford an important illustration of the "law of minimum" applied to essential nitrogenous components of the food supply.

Our experience regarding the comparative value of different proteins and a knowledge of the need of certain accessory substances, "vitamines," or "food hormones," such as are present, for example, in our "protein-free milk" and in butter-fat, having given us an insight into the essentials of nutrition, we have been in a position to extend the series of experiments undertaken to determine the value of several of the widely used concentrated feeding stuffs and briefly referred to in our last report.

The by-products rich in protein which are used extensively for feeding domestic animals have heretofore been valued solely on the basis of the *amount* of protein which they contain, no attention having been paid to the qualitative character of the protein. In feeding a diet of which corn or corn meal forms the chief constituent our experiments indicated that better results would be obtained if the corn protein were supplemented by one rich in tryptophane and lysine. Thus economies can be effected by using proper combinations of these relatively expensive food products. Comparisons already have been made by this method of such products as distillers' grains, brewers' grains, wheat gluten, cottonseed flour and meal, fish meal, beef meal, soy-bean flour and meal, and other leguminous meals rich in protein. The results obtained appear to fully justify a continuance of these investigations and their extension to other largely used commercial products.

Our results with cottonseed products have especial interest, since they give no evidence of any trace of toxicity in the commercial preparations of flour and meal which we have used. They also indicate that the proteins of cottonseed supplement those of corn most efficiently, so that products containing these can be more economically used when combined. In experiments in which the inorganic components of the diet were furnished by our "artificial protein-free milk" there was no failure of growth when cottonseed flour was used, thus suggesting that the latter contains the equivalent

of the hormone deemed essential for nutrition and furnished in fat-free milk.

Yeast has been shown to contain food hormones of at least one type, if not more. Added to our "artificial protein-free milk," yeast makes this salt-lactose mixture more efficient for nutritive purposes, so that it closely resembles the highly efficient natural "protein-free milk" in its nutritive potency. The use of yeast as a source of food hormones will enable us greatly to extend the field of our investigations.

As an incident to our studies of "protein-free milk" as a suitable source of the essential inorganic salts, as well as certain food hormones, for nutrition we have found that the mother liquors obtained in the crystallization of commercial milk sugar and now thrown away as useless waste can be made quite as effective as the laboratory-made "protein-free milk" of similar origin. It would appear that in these waste liquors a valuable food product has been overlooked, which is destined to supplement admirably certain natural foods deficient in the milk ingredients. There is no reason why this material should not become available on a commercial scale.

In continuation of more purely biological studies of growth, we have demonstrated, for the albino rat, that after periods of suppression of growth, even without loss of body-weight, growth may proceed at an exaggerated rate for a considerable period. This we regard as something apart from the rapid gains of weight in the repair or recuperation of tissue actually lost. Despite failure to grow for some time, the average normal size may thus be regained at a rate more rapid than that of normal growth.

The success of our mixtures of properly selected isolated food substances as an adequate diet (as well as our caging conditions) for the nutritive welfare of the rat as an experimental animal is attested by the fact that we have maintained an individual in health for more than three years in a small cage on a uniform food mixture containing one isolated protein (casein), starch, butter-fat, and "protein-free milk"; and rats have been carried into the fifth generation on the edestin diet alone. The adequate possibilities of satisfactorily conducting various sorts of experiments under definite and comparable dietary and environmental conditions are thus demonstrated.

Prolonged feeding with foods containing butter-fat or butter-oil show the pronounced stability of the growth-promoting substance contained in butter-fat under ordinary conditions of storage. However, in the butter "oil," in which the growth-promoting factor is more concentrated than in the original fat, gradual deterioration occurs, so that within a year this characteristic potency is almost completely lost.

The possession of a number of rats which had been stunted by dietary procedures at a small size for very long periods of time and

had then resumed growth, as a result of changes in the dietary, has enabled us to determine to what degree this treatment had affected the *physiological* life of the individual. Donaldson states, in his monograph on "The Rat," that "the menopause in females of this species commonly appears at an age of 15 to 18 months, but King reports a female 22 months old—crossed with a male of like age—giving birth to a litter of one." Our own records show females which were stunted to the ages of 538, 380, 396, and 425 days respectively, giving birth to litters of young at 28 months (3 young), 25 months (2 young), 22 months (8 young), and 20½ months (10 young). This indicates that the sexual cycles have merely been delayed by retardation of growth instead of disappearing at the end of the usual chronological period at which fertility is supposed to be lost by albino rats.

Recently we have applied to the growth of chickens some of the dietary experiences gained in the past few years in our studies upon the albino rat. Although the statements in the literature as to the possibility of conducting such experiments were far from encouraging, we have already succeeded in demonstrating the distinction between rations rich and poor respectively in lysine upon the growth of these birds. Thus of two chickens from the same brood kept upon diets strictly comparable except as to their protein constituents, one upon a corn gluten food (low in lysine) gained only 52 grams in 55 days, whereas another on a corn gluten + lactalbumin food (relatively rich in lysine) gained 283 grams in the same period, both having been kept under precisely comparable cage conditions in the laboratory. These results with birds, which agree so precisely with those obtained with rats, practically demonstrate that the amino-acid requirements shown by our experiments with the latter animal may be considered as fundamentally essential to the nutrition of animals in general.

Feeding trials with foods containing "protein-free milk" have shown this to be greatly superior to artificial imitations containing lactose and salts in the same proportion as in the natural product. The known constituents of "protein-free milk" form upwards of 95 per cent of this material; consequently, among the remaining substances, we must seek for those which have such a potent influence over the processes of maintenance and growth. Since our feeding experiments have required the production of large quantities of "protein-free milk," an exceptional opportunity has been afforded for studying those constituents of milk which are present therein in relatively small quantities.

Our experience has long indicated that at least two such substances are present; one, soluble in the butter-fat, is essential for long-continued growth; the other, soluble in water and associated with the non-fat elements of the milk, is required for normal long-continued maintenance. The experiments made by McCollum and his asso-

ciates have led him to the same conclusion and to name these hypothetical compounds fat-soluble A and water-soluble B. The existence of such substances, which was first indicated by Hopkins, and subsequently by many others, notably Funk, who named them vitamines, is now generally recognized, and it is almost universally accepted that they are widely distributed among our ordinary articles of food.

Milk appears to contain all of such substances required for both maintenance and growth, and under conditions which appear more favorable for future attempts to determine their nature than those presented by other food products. It has thus seemed to be advisable for us to attempt to learn as much as possible of the properties of all substances which we can isolate from milk, even in minute proportion. Although most of these will doubtless prove to be of quite subordinate importance in nutrition, a definite and precise knowledge of their amount and properties will greatly facilitate the search for other substances.

The subject of our first paper dealing with the constituents of milk related to the presence of phosphatides in this important food substance. We have since determined the distribution of these phosphatides among the various fractions into which milk is separated in our process of making "protein-free milk."

A previous examination of butter fat, centrifuged at high speed, showed the presence of so small a trace of phosphorus that this fraction may be considered to be practically free from phosphatides. Our present investigation of the "protein-free" milk, *i. e.*, the fraction from which fat and protein had been removed as completely as possible, failed to yield any trace of phosphatides which could be extracted either by alcohol or chloroform. It thus appears that this class of substances is only associated with those fractions which contain protein.

Distribution of Phosphatides in One Liter of Whole Milk.

1 liter whole milk.	Constituents.	Phosphatides.
	gm.	*gm.*
Fats	35.0	None
Casein	29 0	0.0102
Coagulable proteins	4.7	0.0432
Neutralization precipitate	2 5	0 0037
Lactose, salts, etc	57 1	None
	128 3	0.0571

Together with these phosphatides, alcohol extracts from "lactalbumin" a larger quantity of fat-like material which we have not yet been able to investigate. Since the solutions from which the lactalbumin was separated by coagulation are practically water-clear, it seems improbable that these contain appreciable quantities of the higher fats, unless the latter are in some form of combination which is soluble in

water. It is possible that these, like the phosphatides, may be also combined with protein. Similar fat-like products appear always to accompany the lecithins of different origin, and these deserve more attention than they have received in the past. We hope to have an opportunity soon to investigate this long-neglected question.

Much time has been devoted to extending our present quite incomplete knowledge of the proteins of milk, and many data have been collected. The lactoglobulin has been separated from the lactalbumin and the relative proportions and chief characteristics of these two proteins have been more definitely established than in the past.

We have demonstrated the presence, in perfectly fresh milk, of not insignificant amounts of protein having the properties of proteose, and have made preparations in sufficient amount for ultimate analyses and studies of their properties. The alcoholic washings of our casein preparations, as noted in our last report, contain a small amount of protein which has approximately the same degree of solubility in relatively strong alcohol as gliadin from wheat. Time-consuming efforts have been made to determine whether this protein is an original constituent of milk or an alteration product of casein, produced during the precipitation of the latter. While conclusive evidence on this point has not yet been obtained, little doubt remains that it is originally present in perfectly fresh milk.

In making our "protein-free milk," the milk serum, from which the casein was removed by precipitating with dilute acid and the heat-coagulable proteins by boiling, gives a precipitate when neutralized with alkali, which consists of approximately two-thirds calcium phosphate and one-third protein. A part of this protein, probably consists of lecithalbumin, as we have already indicated, but what relation the rest may have to the other proteins of the milk remains to be determined. It is expected that the anaphylaxis reaction will help to solve this question as it has already helped in determining the individuality of the other milk proteins. In carrying out these anaphylaxis tests we have had the hearty cooperation of Professor H. G. Wells, of Chicago. The results which he has obtained illustrate in a most striking way the value of this method for differentiating the several proteins contained in a solution, or in an extract, as well as for demonstrating the completeness of their separation from one another. The results of this study of the milk proteins will be published as soon as the relations of a few new preparations have been determined by the anaphylaxis reaction.

Several attempts have been made to fractionate the "protein-free milk" by crystallization from alcohol of gradually increased strength, in the hope of obtaining evidence of the existence of a growth-promoting alcohol-soluble substance. Thus far no fractions have resulted which showed any favorable influence on the growth of young rats.

It has been shown that an optimum proportion of some amino-acids must be available in the food if a maximum rate of growth is to be attained. This fact makes it of economic as well as scientific interest to know the amino-acid make-up of food proteins, so that suitable combinations of them may be furnished in the diet. Van Slyke's method of protein analysis should furnish information respecting the relative amounts of nitrogen belonging to some of the individual amino-acids as well as to various groups of them. We have consequently given attention to Ritthausen's method for precipitating the total protein from extracts of food products by means of copper sulphate.

We have further devoted our efforts to determining the amount of nitrogen extracted from several seeds by various solvents, as well as to the conditions under which the most could be extracted. As this work is preliminary to more extensive investigations, the results now available will serve as a guide for future studies.

Analyses made in Van Slyke's laboratory, showing the distribution of nitrogen in gliadin and lactalbumin, did not agree, especially in respect to lysine, with analyses made in this laboratory by Kossel's method. Since Van Slyke's method, if reliable, should give a general idea of the peculiarities of the amino-acid make-up of proteins, or products rich in protein, it seemed desirable to cooperate with this investigator in an effort to determine the degree of agreement to be expected between results by the two methods. The outcome has been a substantial agreement, secured by slightly modifying each method. We have also made several other analyses by Van Slyke's method in order to secure data necessary to the development of methods whereby a knowledge of the characteristic features of the amino-acid make-up of the total protein of food substances can be obtained without too great an expenditure of time and labor.

Work on the immunological relations of the vegetable proteins in cooperation with Professor H. G. Wells has been continued. Further studies of the anaphylaxis reaction between proteins from seeds of different genera have shown that typical and severe reactions may sometimes be obtained when proteins isolated from seeds of different genera are employed. In every case such reactions have been developed only by preparations of proteins so nearly alike that differences between them have not been detected by physical or chemical means, or else the differences found have been so slight that it seems highly probable that the proteins concerned are very similar in chemical constitution. Such reactions can be attributed to common reactive groups in these different proteins, evidence of which was given in an earlier paper dealing with the proteins of wheat and barley.

PALEOGRAPHY.

Loew, E. A., Oxford, England. *Continuation of investigations upon ancient Latin minuscule writing.* (For previous reports see Year Books Nos. 9–14.)

During the fall and winter months Dr. Loew saw through the press his transcript of the Bobbio Missal, reference to which was made in his previous report. The volume will be ready for publication as soon as the introduction is printed; but it is necessary to make another thorough examination of the original and of similar manuscripts which may be preserved in the Bibliothèque Nationale. The volume of plates which accompanies the volume of text will probably not see light before the war is over, as the Italian printer depends for his material upon a German firm.

Last June Professor Rand and Dr. Loew discovered the oldest extant manuscript of the letters of Pliny the Younger, the possession of J. P. Morgan, and at the December meeting of the Philological and Archeological Association held at Princeton they read a joint paper on this manuscript. The manuscript has a double claim on the interest of classical scholars. It is three centuries older than the oldest manuscript heretofore used in an edition of Pliny; secondly, it is a member of the best class and, as Professor Rand ingeniously proves, the very manuscript which was used by Aldus in his edition of Pliny's letters, and which has been lost ever since. It is planned to publish a small volume containing the results of their study of the manuscript.

During the winter and spring Dr. Loew gave lectures before the universities of Harvard, Cornell, Princeton, Michigan, North Carolina, and South Carolina.

PALEONTOLOGY.

Case, E. C., University of Michigan, Ann Arbor, Michigan. *Study of the vertebrate fauna and paleogeography of North America in the Permian period, with especial reference to world relations.* (For previous reports see Year Books Nos. 2, 4, 8–14.)

During the summer of 1916 Mr. Case was occupied in following the boundary line between the Permian and Pennsylvanian beds in Kansas, Oklahoma, and Texas, and comparing the Red Beds of these States with those of New Mexico and the Trans-Pecos region of Texas. The eastern border line was followed through Kansas and Oklahoma and south in Texas as far as San Angelo. In this part of the work careful observations were taken of the structure and material of the formations in preparation for an attempt to interpret the paleogeography of the periods in which they were deposited with especial reference to the vertebrate life. In addition to the material gathered on this phase of the work it was determined that vertebrate fossils occur much farther east than has previously been reported,

traces of the typical vertebrate fauna being found near Paul's Valley, Oklahoma, and Blue Grove, Texas. Recognizable fragments were also found south of Abilene, Texas, near Buffalo Gap.

From this point the observations were carried south to San Angelo and thence west to Pecos, Texas. From Pecos the trip was extended north and west into the Rustler Hills and then to Roswell. From Roswell the party turned west through the Capitan and Oscura Mountains to Soccoro, New Mexico. Near Carthage, New Mexico, Red Beds were examined, at the suggestion of Mr. N. H. Darton, of the U. S. Geological Survey, and remains of vertebrates were found for the first time, which showed these beds to be Triassic in age. Other beds were examined in the Valle del Ajo de la Parida region, northeast of Soccoro. Here typical Permian bones were found in the lower part of the beds, the first that have been found in this region; the upper part of the beds was shown to be barren and possibly Triassic.

The expedition resulted in the accumulation of considerable valuable data upon the paleogeography of the Red Beds and in the determination of the age of a part of the Red Beds of New Mexico which have hitherto been called Permo-Triassic.

Hay, Oliver P., U. S. National Museum, Washington, District of Columbia. *Investigation of the vertebrate paleontology of the Pleistocene epoch.* (For previous reports see Year Books Nos. 11–14.)

During the past year Dr. Hay has pursued his investigations on the vertebrate paleontology of the Pleistocene epoch in North America. The holding of the Panama Pacific Exposition at San Francisco offered the opportunity to visit various museums on that coast. Small collections were examined at Salt Lake City and at Portland. Some interesting materials were studied at Leland Stanford University. At San Francisco free access was given to the fossil vertebrate collections at the Museum of the California Academy of Sciences and at the Memorial Museum, both in Golden Gate Park.

However, the principal purpose in going to that coast was to study the materials which have been collected from the asphalt pits near Los Angeles. These materials are principally at the University of California, at Berkeley, and at the Museum of History, Science, and Art at Los Angeles. An astonishing amount of vertebrate remains has been gathered, the study of which will extend greatly our knowledge of the life of Pleistocene time.

Recently Dr. Hay visited Baltimore and Rutgers College, in order to examine various collections.

A week at the end of October was spent in investigating the vertebrate fauna of Pleistocene beds in Florida in which human remains occur, either by primary or secondary deposition.

Since the last report a considerable amount of vertebrate remains, other than that mentioned above, has been studied, much of it sent

in by collectors. A noteworthy specimen is a nearly complete skull of an extinct horse, found in the gold-bearing silts near Dawson, Yukon.

Within the year the writer has published a paper (*Proc. U. S. Nat. Mus.*, vol. 51, pp. 107–123, pls. 3–7), describing a new species of ground-sloth (*Nothrotherium texanum*) and a glyptodont (*Glyptodon petaliferus*), both from Texas. The latter was based by Cope on a half of one plate of the carapace; the writer is able to describe a large part of the skull and skeleton. Both specimens described belong to the U. S. National Museum. In another paper (8th Ann. Rep., *Fla. Geol. Surv.*, pp. 39–76, pls. 1–8) fourteen new species of tortoise belonging to the Pleistocene of Florida were described.

Wieland, G. R., Yale University, New Haven, Connecticut. *Continuation of investigations on fossil cycads.* (For previous reports see Year Books Nos. 2–4, 6–9, 11–14.)

During the year volume II of the American Fossil Cycads was published by the Carnegie Institution of Washington and La Flora Liásica de la Mixteca Alta with atlas appeared in *Boletín 31 del Instituto Geológico de México*. Volume II of the American Fossil Cycads deals primarily with the silicified forms, but is in a certain sense a manual on the cycadeoids. Its logical continuation is a more exacting treatise on anatomy. This is planned, and much of the work of the past year is preparatory to such a continuation. The contribution on the Mexican Liassic enters the broader field of early Mesozoic floras. Of these, whether large or small, there is to-day scarcely one which does not invite restudy.

PHILOLOGY.

Churchill, William, Philadelphia, Pennsylvania. *Research associate in primitive philology.* (For previous report see Year Book No. 14.)

In the past year I have completed the examination of the available linguistic material of the Sissano people who live upon the Arόp-Sēr lagoons along the north coast of New Guinea, 65 miles east of the boundary of the Dutch moiety of that continental island. Although the vocabulary material is of extreme paucity, the intensive study to which it has been subjected establishes this station as one of great critical importance in the identification of the folk migration of Polynesian ancestors out of Indonesia eastward toward their present Pacific homes under the expulsive influence of the Malayan swarm into Indonesia from the west. It reveals to us a fresh chapter in the common history of the dawn of human society, the shattering of a well-established stone-age society by the coming of a society which has attained to the metal culture. When we make the acquaintance of the Polynesians they are found to be living in neolithic culture; their implements are of polished stone. The Malayan races, arriving

in Sumatra at a period which it is not difficult to synchronize with the fifth century before the Christian era (the migration of Arishtan Shar), possessed a metal culture and probably had already passed from the chalcolithic to that of iron or even of the milder steels. With the possession of the better weapon the Malayans wrote upon the history of the Proto-Polynesians in Indonesia the same sort of record which the Armenoid culture of the bronze knife wrote upon the stone age in Europe.

The possession of this linguistic material from Sissano has made it feasible to devote particular attention upon a most important detail in the discovery of the migration tracks. When the first results of these studies were presented in "The Polynesian Wanderings" the hypothesis was advanced, and supported by no inconsiderable evidence, that out of Indonesia two migration tracks of the earliest folk movement were discoverable. One of these was considered to have followed the northern coast of New Guinea, thence through the Solomon Islands to Nuclear Polynesia, the Samoa Stream sufficiently identified by its *terminus ad quem* in the Pacific. The other, similarly distinguished as the Viti Stream, was considered to have followed in Indonesia the southern chain of islands from Java to Timor Laut, thence by way of Torres Straits to the New Hebrides and to an ultimate destination in Fiji and by convection within Nuclear Polynesia to a junction with the other migration of the race. The critical point in establishing this Viti Stream, the Samoa Stream not being disputed by our authorities, lies in the language stations in the Gulf of Papua. The crux of the problem inheres in this question: Was this great mass of Polynesian speech in the Gulf of Papua brought to the Motu and kindred New Guinea folk directly by migrants advancing eastward by way of the easy route through Torres Straits, or did it derive from the northern stream by reverse coastwise voyaging after reaching the eastern point of the island? In this study this critical point has been investigated with great care and evidence has been massed to the proof of the former hypothesis of the Torres Straits migration, for it has been established that the Polynesian material in the languages of the Gulf of Papua could not have derived from the northern stream and that it must have arrived directly from Indonesia through the southern, or Torres Straits, exit of migration. This final point satisfactorily established, these studies now pass from the problems of the early migrations to the more intensive study of the Polynesian speech as we now find it in use over a wider extent of the earth's surface than has been reached by any language family until the discovery of modern means of communication.

At present attention is concentrated upon the mass of manuscript material of Samoan myth and tradition in the preparation of the dictionary of that language. During the year I have put into final

shape for publication some 500 folios of the courtesy phrases of Samoan life (the *fa'alupega*). In this work I have completed the work for the lesser archipelago of Manu'a and have covered rather more than half of that for our other American possession, the island of Tutuila. At the present rate of progress it is hoped to have this specific study completed for the whole of Samoa in the next year. In such work as this it is apparent that two stages are requisite. In the former the unpublished material which has been gathered painfully from not always willing Samoan sages must be edited, translated, and annotated and printed in order to be set within the reach of students. In the latter stage this material must be assembled in a lexicon, with the fullest possible gathering of material derivable from other branches of the language family.

Acknowledgment is to be made of the generous hospitality extended by the University of Pennsylvania, the American Philosophical Society, and the Academy of Natural Sciences of Philadelphia; their library facilities have been placed unreservedly at my disposal, and thus I have been enabled to collate a greater number of the series of transactions of the great learned societies of the world than would be feasible elsewhere in this country; it could be equaled only in the greater centers of scientific life in Europe, and that recourse is for the present closed to the student.

PHYSICS.

Barus, Carl, Brown University, Providence, Rhode Island. *Continuation of investigations in interferometry.* (For previous reports see Year Books Nos. 4, 5, 7–14.)

Professor Barus has just submitted to the Institution a complete account of his recent experiments in interferometry.[1] One part of these researches contains the results of such applications of the displacement interferometer to which advance reference was made in the preceding annual report. The other part treats of the phenomena of superposed identical spectra. The account has been given chronologically, although many of the anomalous features, in which the interferences first presented themselves, were largely removed in the later work; for the methods used in the several papers, early and later, are throughout different. It therefore seemed justifiable to record them, together with the inferences they at first suggested. The pursuit of the subject as a whole was made both easier and more difficult by the unavoidable tremors of the laboratory, inasmuch as it is possibly easier to detect an elusive phenomenon if it is in motion among other similar stationary phenomena; but it is certainly difficult, thereafter, to describe it.

[1] Carnegie Inst. Wash. Pub. No. 249.

It will be convenient to refer to the cases in which one of the two coincident spectra, from the same source, is rotated 180° with reference to the other, on a transverse axis (*i. e.*, an axis parallel to the Fraunhofer lines), under the term "reversed spectra"; while the term "inverted spectra" is at hand for those cases in which one of the paired spectra is turned 180° relative to the other on a longitudinal axis (*i. e.*, an axis parallel to the length of the spectrum). In the book in question[1] the latter are merely touched upon, but they are now being investigated in detail and give promise of many interesting developments. A full account is given of what may be seen with a single grating, the linear phenomenon, as it is called, and which if it stood alone would be difficult to interpret.

The interferences of the reversed spectra are therefore treated by the aid of two gratings, in virtue of which a multitude of variations are inevitably introduced. The linear phenomenon becomes cross-hatched. The phenomena of reversed spectra are thus exhibited in a way leading much more smoothly to their identification. Their resemblance to the diffractions of two independent, spectrally symmetrical half-wave fronts of like origin and under separate control is marked. The effect of the occurrence of trains of beating light-waves is less apparent.

Section III contains a comparison of the interferences of reversed and non-reversed spectra, the latter produced in a way quite different from the author's earlier work. Naturally these in their entirety are even more bewilderingly varied, and particularly so when (in section IV) an intermediate reflection of one spectrum is admitted. But with all this the present work is on more familiar ground, as the author has hitherto, in the publications of the Carnegie Institution of Washington, given such investigations particular attention.

The flexibility of the new methods is well shown in section V, where separated component spectrum beams may with equal facility be made to impinge in parallel or cross each other at any angle, or perhaps both, with the double result visible in the field of the telescope. In case of crossed rays a remarkable phenomenon is shown, in which very small differences in wave-length imply remarkably large differences in rotational phase (virtually resolving power) of the two intersecting groups of interference fringes, due to the wave-lengths, respectively.

Spectra obtained with two gratings, or at times even with one grating, are often annoyingly furrowed with large transverse fringes. These are also investigated and referred to diffractions resulting from residual errors in the rulings. Finally, several examples of the new methods of investigation are given, showing the important bearing of the diffraction at the slit of the collimator in all these experiments. The real or virtual cleavage of a field of diffracted rays as an essential preliminary is here put in direct evidence.

Hayford, John F., Northwestern University, Evanston, Illinois. *Investigation of the laws of evaporation and stream-flow.* (For previous reports see Year Books Nos. 12–14.)

The primary purpose of this investigation is to determine the amount, and the relation to meteorological conditions, of the daily evaporation from a large free-water surface, such as a lake or a large reservoir. In using any one of the Great Lakes for this purpose it is necessary to evaluate the income to the lake from all sources, the outgo, and the change of content of the lake, day by day. The change of content becomes known if the change in the mean level of the whole lake surface is ascertained. The most serious difficulties encountered in determining the change in the mean level of the whole lake surface are those which arise from the fact that changes in the barometric gradients over the lake and changes in the direction and velocity of the wind produce fluctuations in the level of the water-surface at the gage which is the station of observation. One must evaluate these local changes of level with a high degree of accuracy before it is possible to determine the outgo in the form of evaporation. During the year covered by the report attention has been concentrated almost exclusively on the determination of these local barometric effects and local wind effects.

The progress made during the year in determining the barometric effects has consisted merely in securing better values for the eight constants which express the barometric effects upon water-level at a given station. No change has been made in the formula expressing the effects.

As to wind effects, the work of the year has confirmed conclusively the indications which had formerly been secured that it is necessary to take into account the wind velocity and direction for each hour, rather than the mean velocity and prevailing direction for each day. It has also been demonstrated that eight wind-directions must be considered. Four directions are clearly insufficient. At the close of the year an attempt is in progress to determine the lag in the wind effects, to determine whether the effects are cumulative, and to determine the exponent which expresses most accurately the relation between the observed wind velocity and the disturbance of water-level produced by the wind. The exponent was originally assumed, in this investigation, to be 2; that is, the disturbance of water-level was assumed to be proportional to the square of the wind velocity. This attempt is being made by the use of the method of least squares applied to observation equations in which the absolute term in each equation is the change in water-level at a gage in one hour apparently due mainly to changes in winds. The attempt has not progressed far enough to justify confident statements as to its possible success and as to the probable conclusions. The indications are that it will be moderately successful, that the lag in wind effects is probably small,

that the wind effects are probably cumulative to an appreciable extent, and that the exponent in question is slightly greater than 2.

Stream-flow has not yet been studied in this investigation, as the most favorable time is not yet here.

Howe, Henry M., Columbia University, New York, New York. *Research associate in metallurgy.* (For previous reports see Year Books Nos. 6–14.)

The following are the most important items of the 1915–16 work, which has been chiefly on eutectoid carbon steel. This was chosen because it has the simplest constitution.

(1) Determination of the influence of time as distinguished from temperature, in the tempering of hardened steel, on the hardness and micro-structure, showing approximately what longer time at a lower tempering temperature is equivalent to given time at a higher one.

(2) Determination of the influence of the quenching temperature on the hardness, density, constitution, and micro-structure of hardened steel.

(3) The temperature of the transformation, Ar_1, is lowered at least from about 725° to 625°, if not to 520°, by successive accelerations of the rate of cooling, and it is lowered about 5° by raising from 800° to 900° the temperature reached in the heating.

(4) The rise of temperature during the transformation increases with the rapidity of cooling to a maximum which may reach 18°, and with further acceleration of the cooling in turn decreases.

(5) Within wide limits the rate of cooling from 650° down affects neither the micro-structure, hardness, nor tensile properties, unless the cooling from above the transformation range to 650° has been at least relatively rapid.

(6) Lamellar pearlite is present when the cooling is at an intermediate rate, slow enough to allow it to form, apparently through under-cooling, yet not slow enough to allow it in turn to dissociate. This intermediate rate is much faster when the temperature reached in the heating is 800° than when it is 900°, every rise of the heating temperature apparently increasing the stability of the lamellar structure.

(7) Every increment of the rate of cooling increases the tensile strength and lessens the ductility.

(8) Unless the rate of cooling is rather rapid, heating to 900° leads to much greater tensile strength but much less ductility in the steel after cooling at given rate than heating to 800°, probably in part because of the greater stability and coarseness of the lamellar pearlite formed in cooling from 900°.

(9) Other conditions being constant, the micro-structure of the cooled state is determined primarily by the conditions of the last heating and cooling past the transformation range, the influence of prior excursions past this range being in large part effaced by this latest one.

Lewis, E. P., University of California, Berkeley, California. *Photographic investigations of vacuum-tube spectra of gases and vapors.* (For previous reports see Year Books Nos. 3 and 14.)

During the past year Professor Lewis has completed and published a paper on the Ultra-Violet Spectrum of Krypton, which was printed in the *Astrophysical Journal* for January 1916, pages 67–72. The wave-lengths of about 150 lines previously unobserved were measured and some series relations were discussed. Work begun on absorption spectra in the ultra-violet, which was discontinued for a time on account of pressure of work, will shortly be resumed.

Nichols, E. L., Cornell University, Ithaca, New York. *Systematic study of the properties of matter through a wide range of temperatures.* (For previous reports see Year Books Nos. 4–14.)

The general survey of the spectra of the uranyl salts, both as regards fluorescence and absorption, a work of four years, has been completed. The photographs have been measured and the results computed, tabulated, and mapped by Dr. H. L. Howes. The materials thus worked up include the various salts made for us by Mr. Cragwall and numerous additional preparations by Dr. Wilber. In addition to this general survey, the data from which will appear in tabular and graphic form in a monograph on the uranyl salts now in preparation, various more detailed studies have been made or are in progress.

The Nitrates.

A critical examination of the fluorescence and absorption spectra of several forms of crystallized uranyl nitrate has been completed,[1] the special object being the determination of the influence of different amounts of water of crystallization. The nitrate is well suited for such a study, because at least three different hydrates are known besides the anhydrous salt. It is found that the spectra of the three hydrates differ from each other and from the spectrum of the anhydrous nitrate fully as much as do the spectra of as many different uranyl salts. It appears, therefore, that water of crystallization exerts as great an influence upon the vibrating electrons of the UO_2 base as is exerted by the acid component of the salt. The interval between bands was found to increase slightly with increasing amount of water of crystallization. It was also found that each of the numerous series of absorption bands has its origin in the reversing region, the first member of the absorption series being in coincidence with the final member of a fluorescence series. While in many cases either the fluorescence band or the absorption band in the reversing region was absent, so that the actual reversal could not be observed, the positions computed from the frequency intervals of the two series almost always indicate that the above-mentioned relation exists. This is presumably true of all uranyl spectra.

[1]Nichols and Merritt, Physical Review (forthcoming).

THE DOUBLE CHLORIDES.

A detailed study of the double chlorides has likewise been completed.[1] It has already been shown[2] that uranyl ammonium chloride possesses a fluorescence spectrum in which each of the usual uranyl bands is resolved (at +20°) into five components, and that each of these is further resolved into doublets upon cooling to −185°. It had been shown further[3] that this spectrum is completely polarized, the components of each doublet being capable of separation at +20°, so that we have two complete fluorescence spectra and absorption spectra polarized at right angles to one another and systematically related.

These studies have now been extended to include uranyl potassium chloride, uranyl rubidium chloride, and uranyl cæsium chloride, all of which (like the uranyl ammonium chloride) crystallize in pleochroic, triclinic plates and have spectra resolved at +20° and completely polarized. The similarity of the spectra of these four salts is remarkable, all having the same number of bands, similarly arranged in groups of five and forming homologous series with a constant frequency interval.

The interval is very nearly the same for all series and for all the salts, with indications of a barely determinable diminution of interval with increase in the molecular weight. The spectrum of each salt is thus an almost exact replica of that of the others, but slightly displaced in wave-length, the order from red towards violet being K, NH_4, Rb, Cs.

THE EFFECT OF CRYSTALLINE FORM.

To determine whether the structure of the uranyl spectra depends upon crystalline form it was necessary to compare two substances of the same chemical composition but crystallographically distinct. Uranyl ammonium nitrate affords opportunity for such a comparison, since it crystallizes in two different systems—orthorhombic from aqueous solution and trigonal from the acid—in both cases without water of crystallization.

The two spectra, which have been mapped by Doctors Howes and Wilber,[4] differ in the most striking manner as regards the position of the groups, their structure, and the character of the resolution when cooled to liquid air.

Doctors Howes and Wilber[5] have also completed an instructive investigation of the fluorescence of several forms of the uranyl sodium phosphates, a study of especial interest in this connection because these substances range from crystalline powders to semi-fluid masses of varying viscosity. It is found that only the dry, powdered forms have spectra which resolve on cooling. All viscous forms, which are solutions in varying amounts of free phosphoric acid, retain the broad

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[1]Nichols and Howes, Physical Review (2), VIII, p. 364 (1916).
[2]Nichols and Merritt, Physical Review (2), VI, p. 358 (1916).
[3]Nichols and Howes, Proc. Nat. Acad. Sci., vol. I, p. 444 (1915).
[4]Howes and Wilber, Physical Review (forthcoming).
[5]Howes and Wilber, Physical Review (2), VII, p. 395.

unresolved bands even at the temperature of liquid air. This is in accord with Dr. Howes's[1] observations on frozen solutions, a summary of which was recently published, while further material of interest and significance is in preparation for the forthcoming monograph.

Phosphorescence of the Uranyl Salts.

By means of a new form of phosphoroscope, the synchrono-phosphoroscope[2], a study has been made of the phosphorescence of the various uranyl compounds, concerning which but little has been recorded since the original observations of E. Becquerel in 1861. The after-glow in these substances, while brilliant, is very brief, the intensity falling to $\frac{1}{1000}$ of its initial value in a few thousandths of a second. It was found possible, nevertheless, to establish the following facts:[3]

(1) The phosphorescence spectrum is identical in structure with the spectrum of fluorescence, all the narrow bands observable at $-185°$ being present in both.

(2) During the decay of phosphorescence all the different bands decrease in intensity at the same rate, so that there is no change in the relative distributions of energy, and the entire complex, in this respect as in many others, is a unit.

(3) The law of decay[4] differs from that of the phosphorescent sulphides and other substances hitherto investigated in that, while there are three rates or processes following one another, the second process is more rapid instead of being slower than the first, and the third more rapid than the second.

Experiments are planned by which to determine whether this new law of decay is common to all substances for which the phosphorescence is of very brief duration or is peculiar to the uranyl salts and due perhaps to their radioactivity and to the consequent presence of β rays.

The Phosphorescent Sulphides.

The change of color of the phosphorescence of the luminescent sulphides is commonly attributed to the existence of two overlapping bands the intensities of which die away at different rates after the cessation of excitation. By the use of the synchrono-phosphoroscope it has been found possible to establish the actual existence of these bands and to determine their properties in some detail.[5]

In the sulphides of Lenard and Klatt the band of short duration lies in the green, that of long duration partially overlapping, it so that in the spectroscope the appearance is that of a single very broad band. In the barium sulphides the band of long duration is on the side towards the red, in the sulphides of calcium and strontium towards

[1] Howes, H. L., Physical Review (2), VI, p. 192 (1915).
[2] Nichols and Howes, Science, XLIII, p. 937 (1916); also Physical Review (2), VII, p. 583 (1916).
[3] Nichols, Proc. Nat. Acad. Sci., II, p. 328 (1916).
[4] Nichols and Howes, Physical Review (forthcoming).
[5] Nichols, Proc. Am. Philos. Soc., LV, p. 494 (1916).

the violet. The color of fluorescence is a blend of the colors of the two bands, the color of phosphorescence going over rapidly to that of the band of long duration. The band of short duration has never been subjected to quantitative study, but it is possible to do so, since (as was shown in the paper just cited) the band of long duration disappears at low temperatures. Doctors Percy Hodge and Howes have in progress the determination of the law of decay of this band and also of its location in the spectrum.

Lenard has shown that there are in the violet and ultra-violet two and sometimes three narrow, well-defined regions, varying in position for each preparation, which strongly excite the phosphorescence of these sulphides. Dr. H. E. Howe, using the large quartz spectrograph, has obtained the absorption spectra of several of the sulphides and finds absorption bands coincident with these regions, so that it appears that the so-called "bands of excitation" of Lenard owe their activity to the fact that they are regions in which the incident light is strongly absorbed by the phosphorescent material.

Dr. H. E. Howe has also completed a critical study of the sector disk method of measuring ultra-violet absorption and has found it possible to greatly simplify the procedure. The modified method may be employed with any photographic plate which is sensitive in the region studied. A spark between aluminum terminals submerged in distilled water was used as a source of light, and with suitable devices to secure steadiness was found to be extremely satisfactory as far as 0.21μ. With this source Dr. Howe has used the sector disk method in mapping the ultra-violet absorption spectra for a number of derivatives of fluoran prepared by Professor W. R. Orndorff. The results of this investigation are now ready for publication.

More recently Dr. Howe has mapped the ultra-violet absorption spectra of alcoholic solutions of phenolphthalein and five of its halogen derivatives, while Dr. K. S. Gibson (whose work on the effect of temperature on the absorption of the synthetic ruby[1] is completed), has determined the absorption of the same substances in the visible region by spectrophotometric methods. The agreement in the results obtained by these widely different methods in the region where they overlap affords a highly gratifying check upon the accuracy of the work.

The chief object of this study of the phenolphthalein derivatives was to determine what changes in the spectrum accompany the appearance of color that is observed when alkali is added. It was found that the type of the absorption curve changes gradually as the amount of alkali is increased. The great differences in the value of the constants of molecular absorption in the visible regions, for the several solutions, and the approximate equality of this constant in the ultra-violet band, indicate the presence in the solutions of two

[1]Gibson, K. S., Physical Review (2), VIII, p. 38 (1916).

different kinds of absorbing molecules, which, according to the current chemical theory as to the conditions of these phthaleins in dilute alkaline solution, are molecules of two distinct substances.

Mr. W. G. Mallory has in progress a study of the selective radiation of certain oxides of the rare earths. The phenomenon has been known since the time of Robert Bunsen, but its precise relation to ordinary temperature radiation on the one hand and to luminosity on the other has not been precisely determined. A connection with luminosity is strongly suggested by the fact that the emission bands are reversals of the absorption bands of the substance, as in the case of the ruby, and are also identical or nearly so with the emission bands of the oxide under the kathode discharge.

Dr. C. C. Bidwell is investigating the thermal conductivities at high temperatures of certain metallic oxides, employing a modification of the method of Lees. This will be an interesting extension of his recent work[1] on the electric resistance, thermo-electric power, and Hall effect of these oxides. He has also carried his observations on the resistance and thermo-electric power of Fe_2O_3 to the melting-point (1390° C.) and finds a reversible transformation point at 1240°.

Dr. R. W. King is applying an ingenious method,[2] recently developed by him, to the measurement of the thermal conductivity of various metals at high temperatures and has in progress a study of the Hall effect in thin films.

Mr. C. C. Murdock is making satisfactory progress in a study of the behavior of certain photoactive cells with fluorescent electrolytes. This investigation is to be regarded as a continuation of the work of Dr. Percy Hodge[3] and Dr. G. E. Thompson[4] on the same subject, though it deals with an entirely different aspect of the general problem.

Nipher, Francis E., Washington University, St. Louis, Missouri. *Gravitation and electrical action.* (For previous report see Year Book No. 14.)

The following results have been obtained:

1. Discharge from large condenser through lead wires clamped in a grounded line: Positive discharge, wires become explosive and go up in a cloud. Same potential negative, wires fuse and fall in hot globules on paper below, burning it—scorching it.

2. The Boyle-Gay-Lussac constant $\frac{PV}{T}$ varies somewhat with electrical conditions of the gas. It is a minimum when the potential is zero absolute.

3. Electrification of a mass of matter decreases the gravitational attraction of that mass for a suspended mass within a metal shield. (Cavendish Exp.)

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[1]Bidwell, C. C., Physical Review (2), VIII (1916).
[2]King, R. W., Physical Review (2), VI, p. 437 (1915).
[3]Hodge, Percy, Physical Review, 28, p. 25 (1909).
[4]Thompson, G. E., Physical Review (2), V, p. 43 (1915).

PHYSIOLOGY.

Reichert, E. T., University of Pennsylvania, Philadelphia, Pennsylvania. *The differentiation of starches of parent-stock and hybrids.* (For previous reports see Year Books 9–14.)

Dr. Reichert has continued his investigations and is engaged in the preparation of his report upon them. It is expected that the report will be ready for printing in the first part of 1917.

PSYCHOLOGY.

Franz, Shepherd Ivory, Government Hospital for the Insane, Washington, District of Columbia. *Investigation of the functions of the cerebrum.* (For previous reports see Year Books Nos. 4–10, 12, and 14.)

The investigation of the motor functions of the cerebral cortex of the monkey was continued under my direction by Dr. Mildred E. Scheetz, with special reference to that part of the area lying within the central or Rolandic fissure. Not much attention has been directed to that part of the cortex lying within the fissure, perhaps on account of the difficulty of operative technique, but the results now obtained are of special value in connection with the numerous studies of the superficial parts of the motor area. The spatial relations of the areas for the bodily parts within and those outside of the fissure have been worked out in five animals, and these results are being prepared for publication. The results confirm those already reported by me, in showing a considerable individual variation in size and in location of the areas for the different anatomical segments at the bodily periphery.

Two minor studies of the behavior of the same animals which were used in the above-mentioned work have been made and reported by Dr. E. J. Kempf: (1) Did consciousness of self play a part in the behavior of this monkey; (2) Two methods of subjective learning in the monkey *Macacus rhesus*.

During the year experiments were made with patients who gave clear clinical evidence of an interference with the cerebral tracts concerned with motor impulses to determine the similarity or dissimilarity of the phenomena of paralysis and recovery therefrom in man and in the higher animals. For a long time it has been known that if the cerebral motor cortex or tracts be interfered with in an animal the animal may recover its ability to move, and this statement has been shown to be true for all the kinds of animals which have been experimented with. The results of the experiments with man prove that there is no fundamental difference *in kind* between his motor recovery and that of animals, and that the differences are only those of *degree*. This demonstration is absolutely opposed to current beliefs. The results of these experiments led to an investigation of some of the factors influencing the recovery of motor control

in the monkey, the motor cortex of whose brain was destroyed. The facts which have been obtained demonstrate that the so-called motor cortex is not essential for the proper performance of movements. We have also found that certain conditions facilitate the recovery. These facts, and those obtained with paralyzed human patients, are not only of considerable practical medical interest in that they show that a paralysis due to a cerebral lesion is not an irrecoverable condition, but also that, contrary to the beliefs of both physiologists and neurologists, the so-called motor cortex does not have the primacy of function generally accorded it. They point to the necessity for a new explanation or new explanations of certain cerebral functions. For example, if a so-called "voluntary" movement can be executed after the removal or destruction of the parts of the brain (motor cortex or underlying fibers) which have hitherto been considered to be concerned with the production of such movements, we must alter our conceptions of the functions of the so-called motor cells and fibers. At the same time, if such an act of "volition" can be carried out without the parts of the brain which have hitherto been considered to be primarily concerned in such "volitional" acts we must modify the current hypotheses concerning the relations of parts of the brain to mental processes.

ZOOLOGY.

Castle, W. E., Harvard University, Cambridge, Massachusetts. *Continuation of experimental studies of heredity in small mammals.* (For previous reports see Year Books Nos. 3–14.)

During the past year substantial progress has been made in the study of inherited characteristics in guinea-pigs, rabbits, rats, and mice, with special reference to the constancy and interrelations of mendelizing characters.

In the guinea-pig studies attention has been centered on size inheritance in species crosses and on the influence of inbreeding on size. In the rabbit work attention has been given principally to quantitative studies of two color-patterns involving white-spotting, the so-called Dutch and English varieties. Among the rats the selection experiments for modification of the hooded pattern, a mendelizing character, are being continued, now in their nineteenth generation, and the linkage relations of two yellow varieties of recent origin are being studied intensively. The mouse work centers upon a study of the several allelomorphs of yellow, an unfixable because always heterozygous character.

Six minor publications dealing with this work have been issued within the year and an extensive publication dealing with the work on guinea-pigs and rats is now in press.[1]

[1]Since issued as Carnegie Inst. Wash. Pub. No. 241, 218 pp., 7 plates.

It is becoming clear that inherited characteristics fall into three categories: (1) those which sharply mendelize; (2) those which blend without indication of Mendelian inheritance; (3) those which give partial blending with imperfect Mendelian segregation. A satisfactory explanation of the first sort is found in the assumed existence of peculiar chemical substances influencing development, which are localized in particular chromosomes within the germ-cells. Nothing is known as to the mechanism of transmission of blending characters. As to the third sort, they may be supposed to depend partly upon substances localized in particular chromosomes, partly upon substances not so localized, or it may be assumed that homologous chromosomes which are dissimilar gradually lose their dissimilarity during conjugation. Investigation is needed to clear up these uncertainties.

The efficacy of selection, whether natural or artificial, in evolution, is generally conceded, but doubt still exists as to the nature and course of the variations on which selection may act. That they are directly and adaptively produced by the environment finds small support in existing observational or experimental evidence. That a changing environment may induce variation by disturbing the stability of the chemical compounds which constitute the living substance and so leading them to assume new forms seems probable, but as yet lacks verification. The one certain generalization of genetic research is that hybridization is a potent source of variation. But hybridization consists essentially in bringing together into a single organism two somewhat dissimilar kinds of living substance, from the interactions of which new sorts may arise slightly different from either of the antecedent sorts. A further study of hybridization and its consequences seems, therefore, the best present means of extending our knowledge of organic evolution.

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